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Thomas Gardner

4/2/52

THE

PRINCIPLES OF CHEMISTRY,

ILLUSTRATED BY

SIMPLE EXPERIMENTS.

BY

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PROFESSOR IN THE ROYAL ACADEMY OF AGRICULTURE AT THARAND, AND
ROYAL INSPECTOR OF MEDICINE IN SAXONY.

Translated from the Fifth German Edition.

BY

C. H. PEIRCE, M.D.

NEW EDITION, CAREFULLY REVISED.

LONDON:
HENRY G. BOHN, YORK STREET, COVENT GARDEN.
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PREFACE TO REVISED EDITION.

On carefully comparing the American translation with the original, it was found that, in several passages, the meaning of the German author had been completely misunderstood, so as to render the corresponding portions of the text unintelligible. These errors have been rectified.

Some further alterations have been made, with the view of rendering the work more suitable to the English reader. Thus, the degrees of the Fahrenheit scale have been adopted in preference to the Centigrade, the latter, however, being annexed within brackets. The hydrogen scale of equivalents also has been substituted for the oxygen scale, as the former is universally adopted by English chemists, and is becoming more general abroad.

These alterations have appeared desirable, as otherwise the student, upon extending his studies to the larger English works on chemistry, and the transactions of our learned societies, would have found much of the knowledge he had acquired in the perusal of the interesting work before us perplexing rather than useful.

I. W. G.

December, 1851.

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PREFACE.

THE following work has been translated, at the recommendation of Professor Horsford, as a good introduction to the study of chemistry.

Such alterations only have been made in the text, as were required to adapt it to use in this country. Other changes might have been desirable, such as substituting the *hydrogen* for the *oxygen* scale of equivalent weights, the *Fahrenheit* instead of the *Centigrade* thermometrical scale,* the adoption in every instance of a *scientific* instead of a *popular* nomenclature, &c.; but, after due deliberation, it was concluded not to depart from the original, except when absolutely necessary to do so. Where alterations in modes of expression, &c., have been made, the meaning of the author has been carefully retained.

In some few instances, the scientific nomenclature usually adopted in our chemical books has been departed from; but this could not well be avoided without somewhat marring the character of the original work. The changes, however, that have been introduced, will in no way confuse the more advanced student, even if they do not assist the learner.

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* It is highly probable that the Centigrade thermometer will in a few years be generally adopted in this country for scientific purposes.

There has been in many cases great difficulty in rightly translating terms used in the arts and manufactures, for the obvious reason that there must be many *peculiar* technical terms in use in Germany, where arts and manufactures, such as porcelain-making, metallurgy, brewing, wine-making, &c., are so extensively cultivated.

An important part of the labour of translating has been performed by a friend, whose familiar knowledge of the German language has been to me of much value and assistance.

I am also under great obligations to the Rev. Dr. Francis, for his kindness in looking over the pages as they issued from the press, and for many valuable suggestions.

C. H. P.

Cambridge, U. S., Sept., 1851.

INTRODUCTION.

THE rapid progress of experimental science during the last twenty-five years is to be ascribed, in great measure, to the fact that pupils, as well as instructors, have become experimenters. This is especially true with respect to chemistry. For every contemporary of Davy, engaged in experimental researches in this department, there are probably, at present, scores of persons occupied in the same field. The fruits of this labour are to be seen in the improved condition of manufactures; in the more substantial scientific basis upon which many processes, formerly altogether empirical, are now securely fixed; in the progress of agriculture, and the arts generally; and, to some extent, in the progress of medicine.

The course of instruction to which this greatly increased experimental investigation is chiefly to be attributed, namely, *the practical or experimental course*, bears the same relation to the study of text books on chemistry that anatomical dissections do to the perusal of essays on operative surgery, or the solutions of problems in celestial mechanics to lectures on the architecture of the heavens. It is, beyond question, the most efficient method to secure a sound and available knowledge of the science, either elementary or more comprehensive.

Works designed to teach chemistry by experiment are already in use, both here and abroad, but most of them take for granted the possession of expensive apparatus, and a laboratory; scarcely are any designed to bring the practical study of the science within the means of the more elementary schools; and none are to be found suited to the winter-evening firesides all over the country, where the younger and the more advanced of both sexes would delight in chemical experiments, did not the apparently necessary expense of apparatus forbid them.

It is to meet the latter two wants, as well as those of a general text-book, that the work of Professor Stöckhardt, edited by my late assistant, Dr. Peirce, is eminently suited.

The apparatus necessary for many of the most instructive and interesting chemical experiments would cost but a trifle, and less than forty shillings would furnish the requisites for all, or nearly all, the most important experiments, if performed in the simple manner laid down in this book. A few tubes and flasks, a spirit-lamp, some corks, india-rubber and reagent bottles, almost complete the list. In consequence of the extensive adoption of this as an introductory work in the schools of Germany, sets of apparatus to accompany it are advertised by the principal manufacturers.*

The qualifications of this work, as a text-book for schools, are such as to leave little, if anything, to be desired. The classification is exceedingly convenient. The elucidation of principles, and the explanation of chemical phenomena, are admirably clear and concise. The summary, or retrospect, at the close of each chapter, presenting at a glance the essential parts of what has gone before, could scarcely have been more happily conceived or expressed for the wants of a pupil or an instructor.

The book is also well adapted to the wants of teachers who desire to give occasional experimental lectures at a moderate expense,—and of those who design to commence the study of chemistry, either with or without the aid of an instructor.

E. N. HORSFORD,

Rumford Professor in the University at Cambridge, U. S.

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* See next page.

CHEMICAL APPARATUS.

The following list comprises most of the apparatus required for performing the experiments described in the present work, and may be purchased at the annexed prices, either separately or by the set, of Messrs. Jackson and Townson, 89, Bishopsgate-street Within, who will also forward more extended lists of apparatus and pure tests, on application, by post:

			PRICE.		
✓	1.	Two glass flasks for boiling liquids	£0	0	9
	2.	Twelve test-tubes, with a stand	0	1	8
	3.	Ten glass tubes, of different sizes, some bent, with perforated corks	0	1	6
✓	4.	Two glass retorts	0	0	9
	5.	Two glass receivers	0	0	9
✓	6.	One glass spirit-lamp, with brass wick-holder	0	0	10
✓	7.	Three glass jars, to bear boiling	0	1	3
✓	8.	Two glass funnels	0	0	6
✓	9.	Two glass rods	0	0	2
✓	10.	One retort-holder	0	1	0
	11.	A piece of platinum-foil	0	0	8
	12.	Two platinum-wires	0	0	6
✓	13.	A blow-pipe	0	0	8
✓	14.	A tripod, with wire triangles	0	0	10
✓	15.	Two iron dishes	0	0	3
✓	16.	Three porcelain evaporating basins	0	1	4
	17.	One porcelain capsule	0	0	4
✓	18.	A file (triangular or rat-tail)	0	0	4
✓	19.	A piece of wire-gauze	0	0	3
✓	20.	A pestle and mortar	0	0	11
✓	21.	A strip of zinc soldered to a strip of copper	0	0	6
✓	22.	A bar or rod of zinc	0	0	3
			£0	16	0

A more complete and elegant collection of apparatus may be obtained for 25*s.*

A balance, with polished steel beam and brass or glass pans and weights, from 3*s.* 6*d.* to 7*s.* 6*d.* A lamp, with double current and appendages, 15*s.*

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A SYNOPSIS OF THE MOST IMPORTANT CHEMICAL TESTS.
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PART I.

INORGANIC CHEMISTRY.

CHEMICAL ACTION.

1. Every one knows that iron, heated to redness, changes into scales or cinders, and that, exposed to moist air or earth, it is converted into rust; that the expressed juice of the grape gradually turns to wine, and this, again, to vinegar; that wood in a stove, or oil in a lamp, disappears in burning; and that animal and vegetable substances in time putrefy, disintegrate, and finally disappear.

Iron cinders and rust are iron altered in constitution; iron is hard, tenacious, of a greyish-white colour, and brilliant; by heating to redness it becomes black, dull, and brittle; on exposure to moisture it is converted into a powder of a yellowish-brown colour. Wine is altered *must*, in which nothing of the sweet taste peculiar to the grape-juice can be perceived; but it has acquired a spirituous flavour, together with a heating and intoxicating power, which was not in the *must*. Vinegar is altered wine; it has an acid smell and taste, and has lost its spirituous flavour, as well as its exhilarating properties, its tendency being rather cooling and sedative. Search must be made in the air for the oil and wood which have disappeared during combustion; both these substances are converted into vapour or gas, and heat and light are thereupon evolved with the phenomenon of fire. Of a similar nature are the changes which animal and vegetable substances undergo, if kept for a sufficient length of time; they are gradually converted, as they putrefy or decay, into various kinds of gas, some of which emit a very disagreeable odour.

Such processes, by which the weight, form, solidity, colour, taste, smell, and action of the substances become changed, so that new bodies with quite different properties are formed from the old, are called *chemical processes*, or *chemical action*.

2. Wherever we look upon our earth, chemical action is seen taking place, on the land, in the air, or in the depths of the sea. The hard basalt, the glass-like lava, become gradually soft, their dark colour passes into lighter, they crumble to smaller and smaller pieces, and are finally changed to earth. A potato placed in the earth grows soft, loses its mealy taste, becomes sweet, and finally decays. The bud, that sends forth a sickly pale shoot in a dark cellar, when exposed to the light and air grows up a vigorous, firm, and green plant, which, imbibing its nourishment from the moist air and soil, forms from their elements new bodies, not to be found previously in the water or the air. A delicate network of cells and tubes pervades the whole plant, imparting to it firmness; these we call vegetable tissue, or woody fibre. We find in the sap, which passes up and down through these cells, albumen and other viscous substances; in the leaves and in the stalks, a green colouring matter—chlorophyll; and in the ripe tubers, a mealy substance—starch. None of these substances are injurious to health; but if the potatoes grow in the dark and without soil, for instance, in the cellar, there is produced in their long pale shoots a very poisonous body—solanine.

The potato forms one of our most important articles of food. The starch contained in it is not soluble in water, but when received into the stomach, quickly undergoes such a change that it can be dissolved or digested, and then introduced as a liquid into the blood. The blood comes in contact in the lungs with the inhaled air; the blood changes its colour, the air changes its constitution, and the heat which we feel in our bodies is developed. We must conclude, from these changes, that chemical action is going on in our own bodies.

3. As long as a plant or an animal lives, the chemical processes are under the guardianship of a higher mysterious power, which is called the *vital force,* and by which they are constrained to furnish the materials for the structure of the animal or vegetable bodies. The vital force is, as it were, the architect who plans the building, and sees that the requisite materials are procured by the chemical processes, and worked up according to his will. Hereupon arise innumerable new bodies, which cannot be artificially imitated, as, for example, wood, sugar, starch, fat, gelatine, flesh, &c. They are called *organic compounds*, or animal and vegetable substances, in opposition to *inorganic* or mineral bodies, which may be artificially imitated by putting together their constituent parts. When life in an animal or vegetable ceases, the chemical powers obtain the mastery, and these, as if they were the gravediggers of nature, fulfil the old motto—"Earth to earth, and dust to dust." The leaves of the potato plant become yellow, and then brown; they fall off, and are gradually converted into a dark powdery substance—humus. In the course of time even this disappears, with the exception of a little ashes, which cannot take flight with the rest. What here it takes years to bring to pass, happens in minutes if we throw the dry leaves into the fire. The chemical action is in both cases quite similar—the only difference consists in the time in which it is effected; it goes on rapidly, as combustion, under a strong heat, and slowly, as a process of decay, at a moderate temperature. But what appears to us annihilation is only change. The substances which have been, not annihilated, but only rendered invisible by combustion or decay, we find again under another form, with exactly the same weight, in the air; from the air, they are again drawn down to the earth by the chemical processes going on in living plants.

4. We see from this how the inscrutable power of the Almighty appointed the chemical processes for his servants, in order, by their agency, to produce the eternal vicissitude which we daily observe around us in all nature, and to call forth evermore, in uninterrupted succession, new life from death; thus it is self-evident how improving and instructive for every thinking man must be that science which explains

to him this vicissitude, and opens to him a clearer insight into the wonders of creation.

This deeper insight will not only lead the mind of man to higher improvement and perfection, but must also fill it with greater admiration and profounder reverence for Him, who revealed to us in these wonders His unsearchable omnipotence and wisdom.

In another point of view, the interest in chemical knowledge will be most powerfully excited by the useful application which can be made of it in every-day life. Chemistry teaches the apothecary how to compound and prepare his medicines; it teaches the physician how to cure maladies by means of these medicines; it not only shows the miner the metals concealed in rocks, but aids him also in smelting and working them. Chemistry, in connexion with physics, has been the principal lever by which so many arts and trades have been brought to such a degree of perfection within the last few decades, and by its means we have been supplied with the numberless conveniences of life that were not enjoyed by our fathers. It cannot be doubted that the farmer must at once regard chemistry as his indispensable friend, for it is this alone which acquaints him with the constituent parts of his soil, with the proper nutriment of the plants he wishes to cultivate, and with the means whereby he can enhance the fruitfulness of his fields.

5. *Chemical Force or Affinity.*—If a piece of iron be heated to redness, till a thick crust of scales is formed around it, and then weighed, it will be found to have increased in weight; consequently, it must have been supplied with something ponderable from the air. This ponderable substance is a species of gas, called oxygen; by its union with the iron it has become fixed, yet by other chemical processes it can be reconverted into its gaseous form. If this crust of iron is now exposed for a time to moist air, it will gradually become rust, and again weigh more than before; it has attracted and united to itself water, and more oxygen from the air. Accordingly, the crust consists of iron and oxygen; the rust, of iron, oxygen, and water, which have become most closely united with each other;—they are chemically combined. There is a peculiar power, which is considered the cause of this

intimate union, as, in general, of all chemical changes; it is called *chemical power* or *affinity*, and bodies that possess this capacity of uniting with each other are said to have an affinity for each other. Accordingly, iron at a red heat has an affinity for the oxygen of the air, and at the ordinary temperature it has also an affinity for water. A gold coin changes neither its colour nor its weight, whether at a red heat, or exposed to moisture; we thence conclude that gold possesses no affinity for oxygen or for water.

6. A force cannot be seen or grasped; we notice it only in the effects which it produces. If we would know whether a piece of steel possesses magnetic power, we apply a needle, and try whether this is attracted by it or not; we then conclude from its behaviour as to the absence or presence of magnetism. Precisely the same course, that of *experiment*, must be taken, in order to become acquainted with the chemical forces, the affinities of bodies for each other. Every experiment is a question put to a body, the answer to which we receive through a phenomenon, that is, through a change which we observe, sometimes by the sight or the smell, sometimes by the other senses. The question has just been put to iron and gold, whether they have an affinity for oxygen; the iron, converted into black oxide, gave an answer to this question, the unchangeable gold did not. Every change which we perceive, every new property which we observe in a body, is a letter in the language of chemistry. To learn this easily and thoroughly, it is above all things useful for the beginner to exercise himself in spelling, that is, in making experiments. To give directions for this is the object of the present little work. Those experiments only have been introduced, which, on the one hand, can be performed easily, safely, and without great expense, and, on the other hand, seem best adapted to illustrate the chemical doctrines and laws, and to impress them on the memory.

7. There are *four leading questions* which the chemist puts to the different natural bodies.

a.) *Of what are they composed?*—Take, for instance, a piece of bone. How is it affected when strongly heated in a furnace? It becomes whiter, lighter, and less solid than before (bone-ashes). But how is it affected when heated in a covered vessel? It becomes lighter, and black (bone-black). If exposed to boiling water, or to steam, how is it affected? It becomes lighter, and remains white; but in the water is dissolved gelatine. How in muriatic acid? It becomes transparent; the bone-earth is dissolved, and a gristly mass remains, which, when boiled with water, turns to gelatine. What is the action of fire upon the gelatine? In a covered vessel it is converted into charcoal, in an open one it burns and disappears. These few experiments show that the bone contains gelatine which is combustible, and an earth which is not so; they show, at the same time, that it is the carbonised gelatine which, in the second experiment, colours the bone-earth black, and makes it bone-black; that this gelatine dissolves in water, but not in muriatic acid, &c. Gelatine and bone-earth are called the *proximate constituents* of bone, but by continued chemical processes these can be resolved still further, that is, separated into simpler constituents. In bone-earth are found phosphorus, a metal (calcium), and oxygen; in the gelatine, besides carbon, three other bodies—oxygen, hydrogen, and nitrogen. These bodies can be decomposed no further by any known method of analysis, and are therefore called *simple bodies, chemical* or *ultimate elements*. There are now about sixty known elements, and almost every year adds to their number; but this increase is of little importance to chemical science or its applications, for it consists of elements which but very seldom occur. This separating of compound bodies into simple ones is designated by the name of *analysis*.

b.) What changes do bodies undergo when placed in contact with other bodies?—Phosphorus, which is obtained from bones, is luminous in the air, and is gradually converted into an acid liquid; it unites with the oxygen of the air, as the iron did on being heated to redness. If the phosphorus is gently heated, this union is attended with a vivid combustion, and there is formed an acid body which is different from the former; to which, if chalk be added, a new body is formed, very similar to bone-ashes; it is, in fact, artificial bone-ashes. The number of new bodies which may be produced by the union of the elements with each other, or with compound bodies, is infinite; and entirely different substances are often formed, according as the combination takes place under the influence of cold or heat, in water or in air, in greater or smaller quantities. This is *combination* or *synthesis*.

c.) What useful applications can be made of chemical theory and practice?—When the chemist discovers a new body, or a new property in one already known, or a new method of synthesis or analysis, he imparts his discovery to the apothecary, the physician, the farmer, the manufacturer, and the tradesman, that experiments may be instituted for the purpose of ascertaining whether any advantage, facility, or improvement can be derived for pharmacy, medicine, agriculture, or the arts. Phosphorus ignites spontaneously at a gentle heat; it is used in lucifer-matches. Taken into the stomach, it acts as a violent poison; it is at present the most common means for the destruction of rats and mice. The constituents of bone-earth and those of gelatine have been found to be universally present in the seeds of different kinds of corn; the chemist concludes from this, that pulverised bones must yield an excellent manure for corn; the agriculturist demonstrates this by experiments on a large scale. In bone-black the property has been discovered of attracting many substances held in solution in liquids, and of condensing them in itself: on account of this property, it is used for making impure water potable; the sugar-refiner employs it to make brown syrup colourless; with it the distiller purifies spirit from fusel oil. This is *applied* or *practical chemistry.*

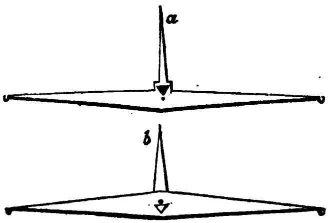
d.) What are the causes of chemical changes, and according to what laws do they take place?—If chemical experiments are performed, as they should be, with the balance in the hand, it will soon be observed, that when two different bodies which can unite with each other are brought together, sometimes a part of the one, sometimes a part of the other, remains free. Further experiments will show how much of one body, in weight, can be united with the other. If all bodies are tested in the same manner, the certainty is finally attained, that all chemical combinations take place only in fixed, unchangeable proportions, and that to every individual body is assigned a definite weight, with which it always enters into any combination whatever. (§ 268.) This certainty is called a *natural law.* Many such laws of nature have already been ascertained, and they serve as a certain guide to the chemist in his labours, since they cannot, like human laws, be arbitrarily evaded or changed. By them alone we attain to a scientific insight into chemical processes, and to the capability of putting direct questions to bodies by experiment, and of testing the truth of the answers received. An explanation of chemical processes based on natural laws, which presents a clear idea of the subject to the mind, is called a *Theory*.

WEIGHING AND MEASURING.

8. *Weighing.*—The balance is to the chemist what the compass is to the mariner. The ocean was indeed navigated before the discovery of the compass; but not till after this could the sailor steer with confidence to a certain place, and recover his proper course, however often lost. And so, in chemistry, no systematic method of study could be pursued before the introduction of the balance. The balance is the plumbline, as well as the touchstone in chemical experiments; it teaches us how to ascertain the true composition of bodies, and shows us whether the questions put, the answers received, or the conclusions drawn from them, are correct or false. Hence it cannot be too strongly recommended to those commencing the study of chemistry to use the balance even in simple experiments. For the experiments described in this book, a common apothecaries' balance is all that is requisite.

Such a balance consists of a brass or steel lever (beam), with arms of equal length, through the centre of which passes a steel wedge-shaped axis, resting on a hardened plate, so that the beam, to the extremities of which the pans are attached, may easily vibrate. It is essential that the axis should be in the right place in the beam, a little *above* its centre of gravity, as in Fig. 1, *a*. The centre of gravity can be found by balancing the beam on its flat side, with the index attached to it, upon a knitting-needle, and when the beam rests horizontally, the point of the needle designates the centre of gravity. If the axis be placed too low *beneath* the centre of gravity, as in Fig. 1, *b*, the beam will

Fig. 1.



overset, if one of the pans is more heavily loaded than the other. If placed directly in the centre of gravity, the balance itself will cease to vibrate when the beam is in an oblique position. When the axis is too high above the centre of gravity, the balance loses much of its sensibility. This latter defect occurs most frequently, but is easily remedied by lowering the axis.

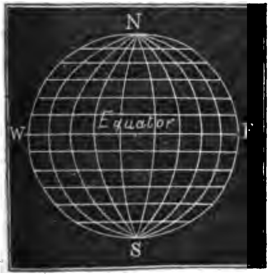
9. The apothecaries' weight and the French decimal weight are those commonly used. The following is the table of the apothecaries' weight, which will answer for all the experiments given in this book:

Pound.		Ounces.		Drachms.		Scruples.		Grains.
1	=	12	=	96	=	288	=	5760
		1	=	8	=	24	=	480
				1	=	3	=	60
						1	=	20

10. The new French system of *weights* and *measures*, which is now almost universally adopted by chemists, is characterised by great simplicity, all its divisions being made by ten; hence the name *decimal* weight and measure. Its unit is derived from the size of our globe.

In order to define the different localities on this globe, imaginary circles, as is well known, have been drawn around it. Those which pass round the earth from east to west, the largest of which is the equator, are called parallels of latitude (circles of latitude); those which pass round the earth lengthwise, intersecting at the poles, *meridians* (circles of longitude). The parallels of latitude gradually become smaller towards the poles; the meridians, on the contrary, are all of equal size. The circle, N E S W N represents a meridian or circle of longitude. The fourth part of this circle, or, what is the same thing, the fourth part of the circumference of our earth, as N E, is the basis of the French system. This quadrant was divided into ten million parts, one of which was taken as the unit, under the name of *meter*. A meter is about three feet and a quarter in

Fig. 2.



length. The smaller measures are produced by dividing by ten, and are designated by Latin terms; the larger ones by multiplying by ten, and are designated by Greek terms.

Smaller Measures.			Larger Measures.		
Meter.			Meter.		
Decimeter	= $\frac{1}{10}$	meter.	Decameter	= 10	meters.
Centimeter	= $\frac{1}{100}$	"	Hectometer	= 100	"
Millimeter	= $\frac{1}{1000}$	"	Kilometer	= 1,000	"
			Myriameter	= 10,000	"

The system of weights was derived from the measure of length, in the following manner. A cubical box was taken, measuring exactly one centimeter in each direction, and this was filled with water at its greatest density (at the temperature 40° F. (4° C.); the weight of this quantity of water was called a *gramme*. This is taken as the unit of the decimal weights, and is multiplied or divided by ten.

Smaller Weights.			Larger Weights.		
Gramme.			Gramme.		
Decigramme	= $\frac{1}{10}$	gramme.	Decagramme	= 10	grammes.
Centigramme	= $\frac{1}{100}$	"	Hectogramme	= 100	"
Milligramme	= $\frac{1}{1000}$	"	Kilogramme	= 1,000	"
			Myriagramme	= 10,000	"

One gramme is equal to 15.43279 grs. Troy.
One kilogramme is equal to 2lb. 3oz. 4.17dwt. Av.

It is well enough known that the body whose weight is to be ascertained must be put into one scale, and in the other, weights sufficient to restore the index to its original perpendicular position. The weight of a body thus determined is, in scientific language, called its *absolute weight*. Thus, a piece of sugar weighing two ounces has an absolute weight of two ounces; or, if a vessel be filled with two pounds and one ounce of water, this water has an absolute weight of two pounds and one ounce.

SPECIFIC GRAVITY.

11. Ice floats in water, iron sinks in it, because the former is lighter, the latter heavier, than water. But if we put a piece of ice in spirit it sinks, or if we put a piece of iron upon quicksilver or mercury, it floats; consequently, ice is

heavier than spirit, iron lighter than quicksilver. It also follows that spirit is lighter than water, since it can support less weight, and quicksilver heavier than water, as it can bear a greater weight. The terms heavier and lighter, in this sense, correspond to what in scientific language is called *specifically heavier* or *specifically lighter*, and *equal bulks* are always to be understood in speaking of the comparative weights of bodies. The expression, *ice is lighter than iron*, means, therefore, that taking equal bulks of each, the former weighs less than the latter; and when we say that quicksilver is heavier than water, we mean that in equal volumes, as a pint, for instance, the quicksilver has a greater weight than the water. But in absolute weight, no regard is paid to the volume of substances.

In order to ascertain *how many times* heavier quicksilver is than water, or iron than ice, it is only necessary to weigh equal volumes or portions of each, and to compare their weights. If, for example, we take five vessels, each of which would contain exactly 100 grains of water, and fill them respectively with spirit, ice, water, iron, and quicksilver, the following differences in weight will be found: the vessel with spirit would weigh 80 grains; with ice, 90 grains; with water 100 grains; with iron, 750 grains; with quicksilver, 1350 grains.

To facilitate the comparison of the numbers which denote how much greater the specific gravity of one body is than that of another, water has been fixed upon as the standard or unit. Therefore, in the above case, the question is, how much lighter than water are spirit and ice, and how much heavier are iron and quicksilver? or, in other words, how many times is 100 contained in 80, 90, 750, and 1350? The other numbers, then, are to be divided by 100, the weight of water, and there is found for

Spirit, $\frac{80}{100}$, or, in decimals, 0.80; it is therefore $\frac{1}{5}$ lighter than water.

Ice, $\frac{90}{100}$, or, in decimals, 0.90; it is therefore $\frac{1}{10}$ lighter than water.

Iron, $\frac{750}{100}$, or, in decimals, 7.50; it is therefore $7\frac{1}{2}$ times heavier than water.

Quicksilver, $\frac{1350}{100}$, or, in decimals, 13.50; it is therefore $13\frac{1}{2}$ times heavier than water.

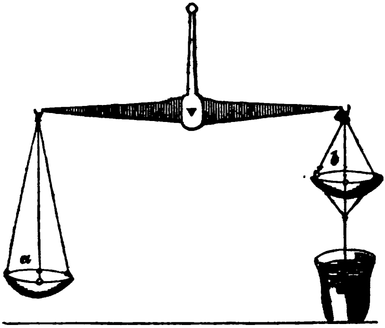
These numbers represent the *specific weights* (sp. gr.). Thus, according to calculation, spirit having a specific gravity of 0.80, 80 parts of it would occupy the same space as 100 parts of water; therefore it is only four-fifths as heavy as water, or, what is the same thing, one-fifth lighter than water. The specific gravity of quicksilver being 13.5, that is, 13½ parts of quicksilver do not take up more space than one part of water; since it is 13½ times heavier than water.

12. *Determination of Specific Gravity.—Experiment.*—To determine the specific gravity (the density) of a fluid, a vial is weighed, then filled with water, and again weighed. This gives the weight of the water. Now pour out the water, and refill the vial either with spirit, syrup, lye, beer, or some other liquid, and ascertain by the balance the weight of each. Then divide the weight of each of these fluids by the weight of the water, and the quotient indicates the specific weight. It is very convenient to use a vial made to contain exactly 1000 grains of water, as then, without any calculation, the number of grains which such a vial contains of any liquid expresses its specific weight.

13. *Experiment.*—Weigh a bottle filled with water; then place a half-ounce weight on the pan which holds the weights, and by the side of the bottle nails enough to adjust the beam. Remove both the nails and the bottle from the pan, and put the nails into the bottle. A bulk of water will be displaced equal to that of the nails; to determine its amount, replace the bottle, after it has been thoroughly wiped on the outside, upon the pan, and remove weights from the other pan until the equipoise is restored. The weights taken away (about 32 grains) form the divisor, and the half-ounce, or 240 grains, the dividend; the quotient $\frac{240}{32} = 7.5$, is the specific gravity of iron, of which the nails were made.

14. *Experiment.*—If we have to determine the specific gravity of a piece of iron, or of any other body which cannot be put into a bottle, it must be fastened by a piece of fine thread to the pan of a common balance (Fig. 3, *b*), the cords of this pan having been previously shortened. Weigh the body first in air, and then in water, immersing it an inch deep. When it is immersed, the opposite pan falls; consequently iron must be lighter in the water than in the air. If the iron in the air weighed half an ounce, then, in order

Fig. 3.



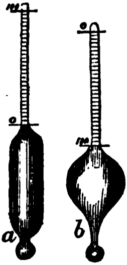
to restore the equilibrium, it will be necessary, as in the former experiment, to remove from the pan *a* 32 grains, equal to the weight of the bulk of water displaced by the iron. The loss of weight is the same, whether the water be removed from the vessel or merely displaced within it. This forms the divisor, and 240, the weight of the iron in the air, the dividend, giving the quotient $\frac{240}{32} = 7.5$.

15. Every substance becomes as much lighter in water as the quantity of water displaced weighs; this is a law of nature. If it displaces less water than its weight in the air, it sinks; if more, it floats. Even very heavy bodies can be made to float by increasing their volume; ships are constructed of iron, although it is eight times heavier than water; a tumbler floats upon water, and yet the specific gravity of glass is from three to four times greater than that of water. A thick piece of iron, weighing half an ounce, loses in water nearly one-eighth of its weight; but if it is hammered out into a plate or vessel of such a size that it occupies eight times as much space as before, it then loses its whole weight in water, and will float, sinking just to the brim. If made twice as large, it will displace one ounce of water—consequently twice its own weight; it will then sink to the middle, and can be loaded with half an ounce weight before sinking entirely.

16. *Areometer, or Hydrometer.*—The same body will sink to a greater or less depth in different liquids—deeper in the lighter ones, and not so deep in those which are denser. This has suggested a very convenient instrument for determining the specific gravity of liquids—the *hydrometer*, or *areometer*. This instrument consists of a hollow glass tube, made as represented in Fig. 4. The interior is hollow, and blown out into a bulb at the lower end, to cause it to float;

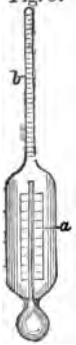
the under part is loaded with quicksilver or shot, to give it a vertical position. The narrow tube serves to denote the depth to which it sinks in any liquid, by means of a scale of degrees, with which it is furnished. There are various instruments of this kind, especially adapted for determining the density of spirits, brandy, oil, lye, syrup, &c. If a hydrometer for weighing spirits is put into water, it sinks only to the lowest point on the scale 0° (Fig. 4, *a*); but in the strongest alcohol, which is much lighter than water, it sinks to the highest point, 100°. A scale for testing lye (Fig. 4, *b*) must, on the contrary, have the 0° point at the top of the scale, to which it would sink in pure water; for, lye being heavier than water, the instrument would be more or less buoyed up in it, according to its strength. In hydrometers for lighter liquids, the degrees proceed from the bottom to the top; in those for heavier liquids, from the top downwards. In most of these scales the degrees are arbitrary; and, in order to convert them into the corresponding specific numbers, tables, constructed for the purpose, must be referred to.

Fig. 4.



17. *Experiment.*—Pour brandy into a cylindrical jar, and observe the degree which it marks on the hydrometer; then put it in a warm place, and, when lukewarm, again note the degree, which will be higher than before, as the heat has expanded the liquid, made it lighter, and, consequently, apparently stronger than it really is. (§ 22.) The specific gravity of all bodies, when warmed, is less than when cold. On this account, in determining the density of bodies, regard should be paid to their temperature, and it has been agreed to consider 60° F. (15° C.) (§ 24) as the mean temperature.

Fig. 5.



In the more accurate hydrometers, the mercury serving as the counterpoise has been ingeniously contrived also to indicate the degree of heat of the liquid, by connecting with it a graduated tube. The small scale, *a* (Fig. 5), denotes the temperature, the long scale, *b*, the density. The small scale is frequently so constructed, that the degrees correspond to those on the long scale, and in order to guard against error it is only necessary to add the degrees below the mean temperature to the density, or to subtract from the density those above.

Gold is nineteen times, and silver ten times, heavier than water; gold alloyed with silver must, therefore, have a less specific weight than pure gold. The specific weight of brass is only = 8. Alcohol and ether are lighter in proportion to their purity and strength, while lye, syrup, the acids, &c., increase in density according to their purity. Hence it is evident how important it is, in many cases, to know the specific gravity of a body in order to judge of its quality.

THE ANCIENT DIVISION OF THE ELEMENTS.

18. *Matter and Forces.*—As we discern in ourselves the visible *body*, and its ruler, the invisible *spirit*, so we recognise in external nature *bodies* which we can handle and weigh, and *forces* or *powers* ruling these bodies and having no weight.

19. *Aggregation.*—The innumerable *natural bodies* which we meet with on the earth may be divided into three great classes; they are either *solid, liquid*, or *aeriform*, and each of these states in which bodies exist is called its state of *aggregation.*

Cohesion.—To divide a piece of ice into smaller fragments, a greater force is requisite than to separate water into minute portions; whence we infer that the particles of the solid ice adhere more strongly than those of the fluid water. A certain attracting power is regarded as the cause of this difference; it acts on the very smallest particles of matter, and is called *cohesion*, or homogeneous attraction. In solid bodies, cohesion is stronger than in liquids, and in aeriform bodies hardly a trace of it can be perceived.

The Ancient Elements, so called.—Of solid bodies, the most widely diffused is earth; of liquids, water; and of the aeriform bodies, air. From this, the ancient philosophers concluded that all solid matter was formed of earth, all liquids of water, and aeriform bodies of air; on this account they called them *elements*, or *primary matter*. They cannot now be regarded as such in a chemical point of view, since they have been decomposed into still more simple bodies; but they may be viewed as *physical* elements, that is, as types of the three aggregate states of bodies.

20. We have no absolute knowledge of the forces of nature, they having, as it were, a spiritual existence. We are, nevertheless, as firmly convinced of their reality as we are of the reality of our own spirit, for we know them by their phenomena and effects. A piece of iron, on being thrown into the air, falls to the ground, which is ascribed to the power of gravitation; if exposed to a moist atmosphere, it rusts; that is, it unites with the oxygen of the air; this is the result of chemical force, and the force of electricity can free the iron again from this union. By the force of magnetism, a piece of iron, when balanced on a pivot, takes a direction from north to south; by the force of heat it can be melted, &c., &c. From this it appears that there are various forces, but it is not improbable that they have one common origin, in the same way that all the different powers of the mind, will, imagination, judgment, &c., are all referred to one single spirit.

Fire, the fourth of the old elements, may be regarded as the symbol of these forces. This also has lost its place among the chemical elements, since it is merely a phenomenon of chemical processes affording light and heat.

Of these ancient elements, fire (heat), water, and air, play an important part in most chemical experiments; heat being influential in promoting chemical changes, and water being the most usual solvent of solid and aeriform bodies. The air deserves consideration in all cases, for almost all chemical experiments are performed in it, and it may exert injurious or beneficial effects upon them. These three so-called chemical elements will, therefore, first be more particularly considered.

WATER AND HEAT.

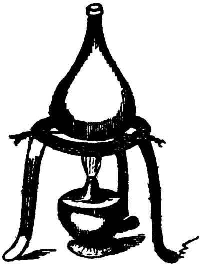
21. WATER covers about three quarters of the surface of the globe; it exists sometimes solid, as at the poles, and sometimes fluid, as in warmer regions. In the form of rivers

it intersects the land in all directions; while it rises in vapour into the air, and, forming clouds, returns in rain to the earth. Hence we find it in nature in all three states of aggregation, and it is obvious that these external differences are caused by the agency of *heat*. Hence water is peculiarly well adapted to serve as a study of the most important effects of heat.

EXPANSION BY HEAT, AND THERMOMETER.

22. *Expansion of Liquids.—Experiment.*—Counterpoise a flask,—that is, place it on one of the pans of a balance and equipoise it by weights or shot put into the opposite pan; then fill it with water, and note the weight of the latter. Warm the flask on a tripod over a common spirit-lamp, moving it round gently at first, that the flask may heat gradually. The water will soon rise, and part of it run over. When it begins to boil, remove the lamp and let the vessel cool, and the water will then sink lower than it stood before. How much has been displaced is found by its loss in weight; it will amount to about $\frac{1}{23}$ of the first weight.

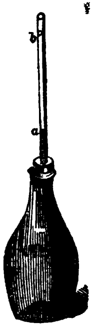
Fig. 6.



The burning spirit, or alcohol, heats the bottom of the glass vessel, which in its turn communicates heat to the water. The heat expands the water, consequently it occupies a greater space than before, and part of it must run over. Hence it follows that warm water must be lighter than cold water. If a pitcher filled with two pounds of ice-cold water be afterwards filled with boiling water, it will weigh about an ounce and a half less.

The same occurs with all other liquids, and, indeed, also with solids and gases: hence, it may be stated as a natural law, *that all bodies expand by heat, and contract on cooling.* But the amount of expansion is very different in different bodies at the same temperature; alcohol, for example, expands two and a half times more, mercury two and a half times less, than water. When fluids are to be bought and sold by measure, an advantageous application may be made of this principle. If a hundred measures of brandy or alcohol are purchased in hot, and sold in cold weather, there will be a loss of four or five measures; therefore we should gain by buying in winter and selling in summer.

Fig. 7.



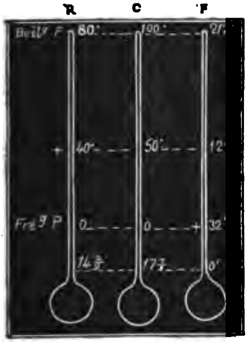
23. *Experiment.*—In order to observe more accurately the expansion of water by heat, adapt to a flask a cork, rendered so soft by gently striking it with a piece of wood that it may be exactly fitted to the opening by mere pressure; perforate the cork with a round file, and make the hole just large enough to admit a glass tube. Fill the flask with water, so that, when the cork is firmly pushed in, the water shall stand at about *a* (Fig. 7), and heat it as in the former experiment.

The water, which in the former experiment was displaced from the flask, now rises in the tube, and this higher in proportion to the smallness of its bore. By this means very slight changes of space are rendered visible, and these deviations may be applied to the *measurement* of heat. This is done by particular instruments called thermometers.

24. *Thermometer.*—Water might be employed for measuring heat, by marking the boiling and freezing points, and graduating the intervening space; but mercury is far better adapted to the purpose, as it boils and freezes at greater extremes of temperature, and becomes hot and cold more quickly; hence it more quickly denotes the variations of heat and cold.

The vessel containing the mercury may also be regarded as consisting of a flask and tube, but which, instead of being joined by a cork, are composed of one entire piece. Having introduced into it a sufficient quantity of mercury, and sealed the open end by fusion, it is immersed in melting snow, and the point to which the quicksilver falls is marked *freezing point*; that to which it rises in boiling water, *boiling point*. The space between these two points can now be divided into degrees, to form the *scale*. The degrees below the freezing point must be of the same dimensions as those above. There are several scales in use, though it is to be regretted that more than one has been adopted. The most common are the three following:—*Reaumur's* (R.), divided into eighty degrees; the centigrade of *Celsius* (C.), into one hundred; and *Fahrenheit's* (F.), into one hundred and eighty degrees. The difference between these can be easily seen in the annexed figure.

Fig. 8.

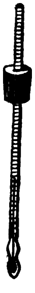


According to R. water freezes at 0° and boils at 80°; according to C. it freezes at 0°, and boils at 100°; according to F. it freezes at +32°, and boils at 212°.

Fahrenheit, a philosophical-instrument maker, commenced reckoning, very strangely, not at the freezing point, but at 32° below it. His scale is still in common use in England, and the high numbers found in English works are thus accounted for. In Germany, ***Reaumur's*** thermometer is used, except for scientific purposes, when the ***Centigrade***, in common use in France also, is employed. That of Fahrenheit has been adopted in this work. In order to compare these thermometers with each other, it need only be remembered that 4° R. are as large as 5° C. or 9° F. In reducing the degrees of Fahrenheit's scale above 32° to those of the Centigrade, the number of degrees above or below 32° must be multiplied by 5 and the product divided by 9. And to reduce those of Fahrenheit to Reaumur, the number of degrees above or below 32° must be multiplied by 4 and divided by 9. To the degrees above 0°, the sign + is prefixed or understood; to those below, the sign — is invariably added.

A cylindrical thermometer, graduated to 572° F., is best suited for chemical experiments; as shown in the annexed figure, because it can be easily adapted to a perforated cork, and then fitted to a flask, in which liquids are to be heated to a certain temperature. The degrees above the boiling point are to be divided off at distances equal to those below.

Fig. 9.



25. Quicksilver freezes at —40° F. (—40° C.) In the northern regions of the earth a degree of cold of —58° F. (—50° C.) has been observed, and by artificial means the temperature can be lowered to —148° F. (—100° C.) When great degrees of cold are to be measured, alcohol is used in the construc-

tion of this instrument, as it does not congeal at —148° F. (—100° C.)

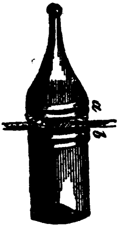
26. Quicksilver boils at 680° F. (360° C.); therefore its use must be limited to temperatures below this point. The high temperatures attending ignition are measured by the expansion of bars of platinum, a metal which does not melt even in the hottest furnace. Such an instrument is called a pyrometer. By means of lenses, and by chemical action, a degree of heat of more than 3632° F. (2000° C.) may be produced.

27. *Expansion of Solids.*—If an iron vessel, when cold, is just large enough to pass through the door of a furnace, it cannot be removed from it when heated. The iron bands or tires of carriage-wheels are applied while red-hot to the frame, and on cooling they contract and bind the wood-work together with great force. A metallic disk, which, when red-hot, fits exactly into a circular box, will, on cooling, become loose, and shake in it. The tire and the disk both become smaller on cooling. These examples show that solids also are expanded by heat and contracted by cold, and explain many of the phenomena of common life. Clocks go faster in winter, and slower in summer, because the pendulums elongate in summer, and, consequently, vibrate slower; while in winter they become shorter, and vibrate more rapidly. A piano gives a higher tone in a cold than in a warm room, on account of the contraction of the strings. A nail driven into the wall becomes loose after a time, because the iron expands in summer and contracts in winter more than the stone or the wood, and thus the opening is gradually enlarged. For this reason, in the construction of railroads, the rails must not be laid too close together; in the arrangement of steam-pipes, these must not be too firmly inclosed; in roofing, the zinc plates, instead of being nailed *together*, must overlap each other, that they may neither tear nor warp on alternate contraction and expansion.

Brittle bodies, as glass and porcelain, expand or contract so rapidly, by sudden heating or cooling, that they break.

Experiment.—Wind round a vial two bands of paper, *a* and *b*, Fig. 10, and secure them firmly with thread; pass a piece of string round the vial, between these folds of paper, and move the vial quickly to and fro on the string until the latter breaks. Then immediately pour cold water upon the place, and the glass will break as evenly as if cut. The sharp edges can be removed with a file. In this manner, common vials and eau-de-Cologne- and even larger bottles, may be converted into vessels adapted to chemical and other purposes.

Fig. 10.



It is well known that heat is produced by the friction of two bodies upon each other; that by sliding quickly down a line or a pole by the hands, these will be burnt; and that rapid motion will ignite the axles of a carriage, unless they are well greased. Thus, in the above experiment, the friction produced great heat in the glass, the string emitted a burnt odour and broke, and great expansion of the glass was produced. When the outer surface was suddenly cooled by the cold water, the expanded particles at once contracted, and more rapidly in the external particles than in those of the inner surface, causing the fracture of the glass, and the more easily the greater its thickness. If the temperature had been slowly reduced, it would not have broken.

Thus it is obvious (*a*) that glass and porcelain vessels intended for sustaining high temperatures, such as flasks, alembics, retorts, capsules, &c., should be thin, particularly at the bottom; and (*b*) that, when used, they should always be gradually heated and cooled.

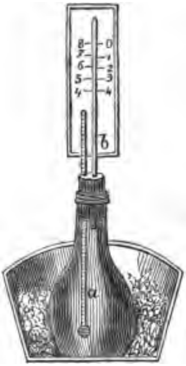
The above method of heating glass by a piece of string furnishes the chemist with a simple expedient for removing stoppers which are too firmly fixed in the bottles to be taken out by turning or tapping them. All that is necessary is to wind a piece of thick string round the neck of the bottle, and move it quickly until sufficient heat has been produced to loosen the stopper.

No two solids expand alike; the metals expand the most, and all solids less than fluids.

The expansion of *gaseous* bodies will be considered under the head of air. (§ 97.)

28. *Expansion by Cold.*—A remarkable exception to this law of expansion by heat and contraction by cold occurs in the case of water.

Fig. 11.



Experiment.—A large flask is arranged as directed in experiment 23, but inserting a cylindrical thermometer, *a*, through a second hole made in the cork. The flask is filled with water to the top of the tube *b*, and placed in a vessel filled with snow. A strip of paper may be pasted on this tube, upon which the level of the water may be marked as the thermometer falls. The water as it cools will sink in the tube until the mercury stands at 40° F. (4° C.); yet, on cooling still more, it does not fall any further, as we should expect it would, but, on the contrary, it begins to rise again, and continues to do so till it reaches the freezing point. At 32° F. (0° C.) it stands at the same point as when its temperature was at 46° F. (8° C.) Water is accordingly most dense at 40° F. (+4° C.); all other liquids continue to increase in density as they cool.

29. However unimportant this exception may appear at first, our admiration must be the greater when we reflect upon its consequences. Were it not for this, our country would have the climate of Greenland. The freezing of our waters, as the winter sets in, is principally owing to the coldness of the atmosphere. Consequently, the upper part of the water is colder and heavier, and sinks to the bottom; the warmer water ascends, becomes cold, and also sinks. If the water continually became denser, to its freezing point, this circulation would continue till the whole mass of water to its greatest depth reached 32° F. (0° C.), and a few cold days would suffice to convert all our ponds, lakes, and rivers into ice. This does not happen, because the circulation ceases when its temperature has fallen to 40° F. (4° C.), when the water, though yet colder, becomes lighter, and floats on the surface. Thus, freezing can only take place at the surface, and the ice be but gradually formed. At a small depth below the ice the water always retains the temperature of 40° F. (4° C.)

MELTING OF SOLIDS.

30. The expansion of bodies is the first general effect of

heat; but in solid bodies another effect is observed; they change their state of aggregation, they become liquid, they *melt*. Many of them become *soft* before melting, so that they can be kneaded; for instance, butter, glass, and iron; in this condition, glass can be bent and moulded like wax, and iron can be forged.

Experiment.—Hold a piece of a small glass tube in the upper part of the flame of a spirit-lamp, revolving it slowly between the fingers; when red-hot, it will be so soft that it can be bent into any shape desired. Thus are easily formed any of the numerous bent tubes required in chemical experiments. For softening larger tubes, a lamp with a double current of air must be used, as this gives a much stronger heat than the simple lamp. To break a glass tube, a scratch is made upon it with a three-cornered file, at the place to be broken, and then it can be parted by gently bending it with both hands.

Most solid bodies become *suddenly fluid*, as ice, lead, &c.

31. *Experiment.*—Place one vessel containing snow or ice, and another containing a piece of a tallow-candle, on a warm stove, dipping a thermometer from time to time into the melting substances; the temperature will remain stationary in the first vessel at 32° F. (0° C.), in the other at about 100° F. (38° C.), so long as any ice or tallow remains unmelted, but when the melting is complete it will commence rising. The degree of heat at which a body melts is called its *melting point.* Every substance has its own melting point, sometimes above and sometimes below the freezing point; for example, lead melts at above 572° F. (300° C.), silver at above 1800° F. (1000 C.); solid quicksilver at —40° F. (—40° C.) If the two vessels containing the melted ice and the melted tallow are placed in the cold, it will be observed that the tallow soon hardens at about 95° F. (35° C.), but the water does not until the mercury has fallen to 32° F. (0° C.) Thus the congelation of fluids takes place at about the same temperature as that at which they pass from the solid to the fluid state.

Many substances, charcoal for instance, have never yet been melted, and others have never been frozen, as, for instance, alcohol; but it is very probable that, when some method of producing still greater degrees of cold and heat is discovered, we shall succeed in rendering all solid bodies liquid, and all liquids solid.

32. *Latent Heat.—Experiment.*—Put two vessels of equal size on the top of a warm oven, one of them containing a pound of snow at 32° F. (0° C.), and the other a pound of water at 32° F. (0° C.); when the snow is melted, remove them both. By the touch merely it will be perceived that the snow-water is still cold, while the water in the other vessel has become warm; and the thermometer will indicate that in the former the temperature is at 32° F. (0° C.), in the latter at 167° F. (75° C.) As both vessels have received equal degrees of heat, and when placed upon the oven were of the same temperature; the question suggests itself, What has become of the 167° of heat imparted to the vessel filled with snow? The reply is, This heat has been absorbed by the snow, thus converting it into a fluid,—melting it.

Experiment.—Put one pound of snow at 32° F. (0° C.) into the vessel containing the water heated at 167° F. (75° C.), and then examine it with the thermometer; as soon as all the snow has disappeared, the quicksilver will fall to the freezing point. Consequently, the snow has taken from the hot water 167° F. (75° C.) of heat, and has thus become liquid.

33. *Experiment.*—This heat has by no means been annihilated in the water, but is concealed there (latent), and continues thus hidden as long as the water exists in a fluid state. But it will again become free, or sensible to the touch, when the water assumes a solid form. This may be rendered obvious by sprinkling $\frac{3}{4}$ of an ounce of water upon $1\frac{1}{2}$ ounce of quick lime; the lime swells, becomes very hot, and finally crumbles into a fine powder. If this is weighed when cold, it will be found to have increased in weight by half an ounce; thus two ounces of slaked lime have been produced from an ounce and a half of quick lime; the quarter of an ounce of water missing has passed off as steam. The water alone can have produced this increase of weight by combining chemically with the lime; and it can exist there only in a solid state, as the slaked lime is an entirely dry pulverulent substance. This great development of heat is explained thus: partly because the water, in becoming solid, gives up the heat which it had absorbed in passing to the fluid state, and

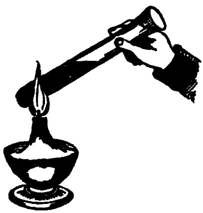
partly because of the chemical combination between the two bodies taking place with great energy. *A disappearance of heat always ensues when solid bodies become fluid; but an evolution of heat, on the contrary, when liquid bodies become solid;* and thus is explained very simply, for example, why the air remains cool when the snow and ice are melting in the spring, and why the weather moderates on the fall of snow.

That heat which is felt by us, and which is indicated by the thermometer, is called *free heat;* it has but a feeble affinity for bodies, and easily leaves them on cooling. That imperceptible heat on which the fluidity of liquid bodies depends, and which on freezing escapes or becomes free, is called *latent heat.* Hence a fluid may be regarded as a combination of a solid with a latent heat.

BOILING AND EVAPORATION.

34. *Boiling of Water.*—Water, as is well known, boils when heated to a certain temperature.

Fig. 12.



Experiment.—Water, to which some sawdust has been added, is heated in a test-tube over a spirit-lamp. The tube is held by the upper part, and rotated for some minutes between the fingers, that the flame may have equal access to all the lower parts of the tube. If the water be carefully observed, it will be seen that the sawdust ascends on the upper surface of the liquid, and descends in the lower strata; the warm water, becoming lighter, rises upwards, while the colder, consequently heavier, water sinks; the water *circulates.* In consequence of this circulation, the heating of fluids takes place more rapidly when the heat is applied *beneath.* Test-tubes are cylindrical glass vessels with rounded bottoms. To prevent their breaking on the application of heat, the bottom must be thin, and blown of a uniform shape. A simple wooden rack, as in the annexed figure, serves as a convenient stand for them.

Fig. 13.

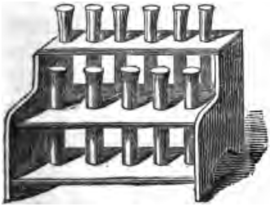
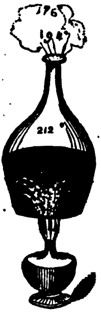


Fig. 14.



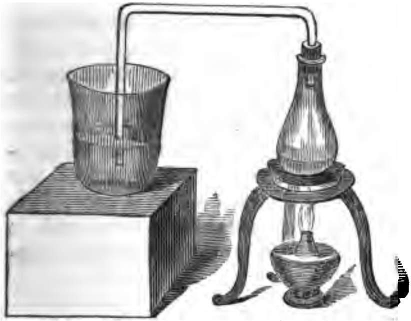
Experiment.—Repeat the former experiment, using instead of the tube a flask, and omit the sawdust, so that the water may remain clear; in a short time numerous little bubbles will appear on the walls of the flask, which will gradually increase in size, and rise towards the surface. These bubbles consist of air, which is expanded by the heat and expelled from the water. All spring-water contains air in solution, and to this is chiefly due its refreshing taste, which is not found in boiled water or in that which has been standing for some time. Afterwards, when the water has become quite hot, larger bubbles appear on the hotter part of the flask, which, also ascending, become smaller, and entirely disappear before reaching the surface of the water; they consist of aeriform water (steam), which condenses as it comes in contact with the cooler liquid above. The collapsing of the particles of water at the places where these steam-bubbles disappear occasions that peculiar noise which precedes boiling, and which is commonly called the *singing* of the water. When the whole mass of water is heated to 212° F. (100° C.), these bubbles no longer condense, but rise to the surface, where, surrounded by a thin film of water, they remain quiescent for a few seconds, and then, their watery mantle again sinking, they finally burst. This is the *boiling* of water. It boils at 212° F. (100° C.); other liquids boil more readily—alcohol, for instance, at 176° F. (80° C.); others again more difficultly—mercury, for instance, at 680° F. (360° C.)

35. *Steam.*—The space above the boiling water in the interior of the flask appears empty, but it is in fact filled with aeriform water, which has displaced the air that was in it. This aeriform water is called *steam*. It is almost 1700 times lighter than water, because a measure of water yields nearly 1700 measures of steam at 212° F. (100° C.) Within the flask the steam is transparent and invisible, but in the open air it ascends in the form of white clouds, which greatly increase if cold air is blown into the flask by means of a glass tube; for on cooling, the transparency of the vapour is disturbed, on account of the formation of drops of water, so small and light as to float in the air. Clouds also consist of this partly-condensed vapour. As the condensation increases,

the drops become so large and heavy, that they descend as rain. A thermometer immersed in boiling water indicates 212° F. (100° C.); if placed in the steam immediately above, it shows the same; and this temperature will not rise higher, however long the boiling be continued, or however strongly the flame of the lamp be urged. This is similar to what occurs in the melting of snow; heat disappears, and its disappearance proceeds from the same cause in both cases; steam requires heat for its existence as such, and is so intimately combined with it that the excess is no longer perceptible,—it is latent. If water may be regarded as a combination of ice with latent heat, so steam may be considered as a combination of ice with still more latent heat; which latter becomes free again on the conversion of steam into water.

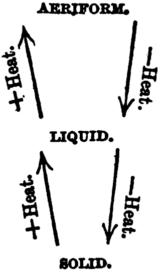
36. *Experiment.*—Adapt the shorter limb of a bent glass tube, by means of a perforated cork, to the neck of a flask, and pass the longer limb to the bottom of a beaker-glass or common tumbler. Pour into each of these two vessels two ounces and a half of ice-cold water, and gradually heat the flask upon a tripod until it boils. Note the time required for this operation. Continue the process until the water in the beaker-glass begins to bubble, and note also the time, which will be found the same as that required for boiling the water in the flask. The steam formed in the flask has no other outlet than through the tube into the water, where it condenses, until the contents of the second glass reach the temperature of 212° F. (100° C.), and boil.

Fig. 15.



Both of the vessels must now be weighed; and it will be found that the flask weighs half an ounce less, and the beaker-glass half an ounce more, than before; consequently, half an ounce has passed from the former as steam, and has been condensed again in the latter; and yet this half-ounce of steam, which itself was not hotter than 212° F. (100° C.), could heat to the boiling point two ounces and a half of ice-cold water. What is the source of these 932 additional degrees of heat? They were latent in the steam, and, on its being condensed, were set free. These were caused by the heat of the spirit-lamp, as must be obvious from the above-noted amount of time consumed. Assuming that the time required to boil the water in the flask was ten minutes, and also ten minutes for boiling the water in the second vessel, it follows, that the same amount of heat which was required for heating two ounces and a half of water was only sufficient to evaporate half an ounce of water; the whole of the heat given out in the last ten minutes from the spirit-lamp must consequently have been converted into latent heat. If half an ounce of boiling water received during the evaporation, the amount of 1060° of heat, then the steam evolved must have given off just as much heat when it again assumed a liquid state; consequently, it must be able to raise the temperature of two ounces and a half of water at 32° F. (0° C.) to that of 212° F. (100° C.)

The property of steam to absorb a large quantity of heat, and to part with it again during condensation, peculiarly adapts it for the heating of other bodies, the burning of them being thus guarded against, as the heat of steam in open vessels can never exceed 212° F. (100° C.) Apothecaries avail themselves of steam in the preparation of infusions, decoctions, and extracts; it serves for many of the processes of cookery, and for the distillation of spirits; it is employed in dyeing and bleaching establishments, and is often resorted to for heating apartments, buildings, laundries, &c.



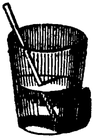
The increase and decrease of heat produced by change of the state of aggregation bodies will be made clear by the annexed diagram. As the steam ascends in the direction of the arrows (by liquefaction and evaporation) heat becomes latent, and as it descends (condensation of vapour and congelation of fluids) heat is liberated.

37. *Aqueous Vapour.*—Water exposed in a vessel to the open air disappears in summer more rapidly than in winter; the heat of the air renders it aeriform,—it *evaporates.* The same happens as in evaporation over the fire, only in the former case evaporation takes place without any visible motion of the water, owing to its becoming aeriform, not throughout the whole mass at once, but upon the surface only. The vapour rises in an invisible form in the air. Warm air, indeed, takes up more of it than cold, but a fixed quantity of it only for each temperature. Thus one hundred measures of air at 32° F. (0° C.) absorb two-thirds of a measure of vapour; at 50° F. (10° C.), one measure and a quarter; at 68° F. (20° C.), two and an eighth measures, &c. If the air has not absorbed all the vapour which it can, it eagerly takes up more, as, for example, when one hundred measures of air at 68° F. (20° C.) contain only one or one and a half measures of vapour; it is then called *dry air*, and wet articles are soon dried in it by rapid evaporation. But if it be already saturated with vapour it is called *moist* air; and damp articles cannot be dried in it, or at least but slowly. If yet more vapour be added to this saturated atmosphere, or if it be cooled, then the excess separates in visible particles, called *mist* or fog when they lie upon the surface of the earth, and *clouds* when they float in the higher regions of the atmosphere. The white smoke which in winter is seen rising from the chimneys, the visibleness of the breath in frosty weather, and the smoking of rivers in winter and after a storm, are phenomena of the same kind.

38. If the cooling of the air is occasioned by a cold solid body, the vapour is then condensed in small drops of water, as may be observed on the outside of a cold glass when brought into a warm room, and the deposit of moisture on the inside of our window-panes, when cooled by the external cold air. The temperature at which this occurs is called the *dew-point*, signifying the temperature at which the air is saturated with vapour.

Experiment.—Fill a tumbler one quarter full with cool water, place in it a thermometer, and at short intervals gradually add ice or cold water, until moisture begins to deposit on the outside of the glass. Then observe the degree indicated by the thermometer, which is the dew-point. If much cold water must be added before the glass clouds over, that is, if the dew-point is much lower than the temperature of the air, fair weather may be expected; while, on the contrary, if the difference between the dew-point and the temperature of the air be but slight, rain may soon be expected, as then the air requires but a slight addition of moisture or increase of cold to become saturated. Instruments by means of which the amount of moisture in the air is ascertained are called *hygrometers.* Many substances readily imbibe moisture from the air, and become damp; such bodies, for instance, as catgut, carbonate of potassa, sulphuric acid, fresh barley-sugar, &c., are called *hygroscopic.*

Fig. 16.

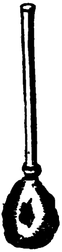


39. *Evaporation* may be accelerated, not only by heat, but also by a current of air, because by this means the air above the surface of the fluid, which is charged with vapour, is removed and replaced by a drier, and, as it were, more thirsty air, which takes up the vapour more rapidly and abundantly than the former. For this reason, the earth dries rapidly after rain, when followed by a high wind, and hence it is necessary in kilns, laundries, drying-rooms, &c., to arrange them in such a manner that the air, when saturated with moisture, may be constantly replaced by dry air.

40. That *heat disappears* during slow as well as rapid evaporation (§ 36) may be readily illustrated by the following experiment.

Experiment.—Fill a tube half full of water, and fasten securely round the bulb of it a piece of wadding; saturate the wadding with cold water, and then twirl the tube rapidly between the hands; presently the water in the tube will become sensibly colder, and the degree of cold may be accurately determined by the thermometer. Moisten the wadding with ether, a very volatile liquid, and twirl it again in the same manner as before; by which means its contents, even in summer, may be converted into ice. Water evaporates slowly, ether rapidly; and both require heat for their conversion

Fig. 17.

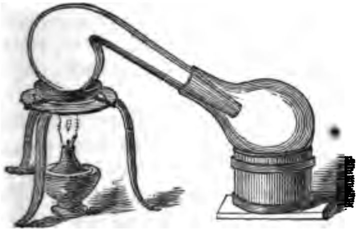


into vapour, and in the above experiment they obtain this heat from the water in the bulb, which is of course the reason of the water becoming cold. On this principle, one feels cool on just leaving the bath, when invested in damp garments, or when the floor of a hot apartment is sprinkled with water. It explains, also, how man is enabled to support the scorching sun of the hottest climates, and even to endure a heat of 212° F. (100° C.), without his blood exceeding the temperature of from 100° F. (38° C.) to 104° F. (40° C.); it is owing to the more copious perspiration, which, by evaporation, renders all the heat above 104° F. (40° C.) latent. If we blow on hot soup, it is also the increased evaporation which cools it more rapidly; but if we blow on the cold hands in winter, they become moist and warm, because the latent heat contained in the vapour of the breath is set free, as the vapour is condensed into water.

41. *Distillation.*—If the condensation of watery vapour be carried on in a closed vessel, the water may be collected as it forms.

Experiment.—A small glass retort is half filled with water, and heated; the steam, as it forms, passes through the neck of the retort into a glass receiver, contained in a vessel filled with cold water, and is there condensed. That the refrigeration may take place more rapidly, the receiver is covered with coarse blotting-paper which is frequently moistened with cold water. This operation is called *distillation* (from *distillare*, to drop), and the pure water obtained is said to be *distilled*. It is purer than spring-water, for this reason, that the non-volatile, earthy, and saline portions contained in all spring-water do not evaporate, but remain in the retort. By this means also very volatile bodies can easily be separated from less volatile ones; as in the distillation of brandy, where the more volatile spirit is separated from the less volatile water. Copper stills

Fig. 18.

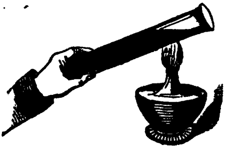


are usually employed for distillation on a large scale, and for condensers vats are constructed, holding serpentine pipes, or *worms*, which present a greater condensing surface than if the pipe had passed straight through the vat. The cold water with which the vats must be filled is very soon warmed by the heat liberated in the condensation of the steam, and must occasionally be renewed by leading off the hot water from above, and letting in a fresh supply of cold water beneath.

DIFFUSION OF HEAT.

42. *Conduction of Heat.* — *Experiment.* — A test-tube, nearly filled with water, is held over a spirit-lamp, in such a manner as to direct the flame against the upper layers of the water; the water will boil at the top, but remain quite cold below. If mercury is treated in a similar way, its lower layers will gradually become heated. The particles of mercury will communicate the heat to each other, but not so the particles of water. Substances through which, as in mercury, heat rapidly passes, are called *good conductors;* but bodies which comport themselves like water are called *bad conductors* of heat. In the former class are included principally the metals, and in the latter, stone, glass, wood, snow, water, and especially soft bodies, as cloth, fur, linen, straw, paper, ashes, &c.

Fig. 19.



The *good conductors* are readily heated, and soon become cold again, as is well known to be the case with iron stoves. A piece of iron feels hotter in the sun and colder in the shade than a piece of wood at the same temperature. The explanation of this delusion of the sense of touch is, that the warm iron conducts the heat more rapidly to the hand, while the cold iron withdraws it more rapidly than the wood is capable of doing.

The *bad conductors* of heat become only slowly heated, and also slowly cooled; for this reason, stoves constructed of brick (the Russian stove) and those made of Dutch tiles, a preparation of clay, retain their heat longer than iron stoves. Bad conductors are frequently employed both for preventing the quick heating and the quick cooling of bodies. Vessels of glass and porcelain are placed on sand (a sand-bath) or ashes, to heat them gradually, and thus guard against their breaking. If a hot liquid is to be poured into them, it must be done by small portions at a time, twirling the vessels round for some minutes before adding more.

On removing vessels from the fire, the precaution should be taken never to place them while hot on metal or stone, but always on some bad conductor, such as straw (straw rings) wood, paper, cloth, &c.; as they are often cracked by sudden cooling and contraction, which is frequently produced even by a current of cold air. Doors of furnaces, ladles, &c., are provided with wooden handles, to prevent those using them from being burnt. Should a person desire to hold a flask or a test-tube while liquids are boiling in them, he must wrap round them several folds of paper, or tie round them a piece of twine, in order that they may serve as a bad conductor between the glass and his fingers. By inclosing substances in bad conductors, the entrance of cold, or, more correctly, the departure of heat, may be prevented; this principle is illustrated in our method of clothing, in the protection given to our wells and trees by covering them with straw, in the preservation of the seeds of plants by snow, and in numerous other phenomena of daily occurrence. Hence bad conductors are frequently called preservers of heat.

43. *Radiation of Heat.*—By conduction, bodies can communicate or abstract heat only when in contact. But heat is felt even at some distance from a fire or from a heated stove, and the earth is warmed by the sun, although a space of millions of miles is between them. This sort of heating is called *radiation of heat.*

Experiment.—Envelop three tumblers with paper, one with silver paper, another with white, and a third with dull black paper, and place them in the sun; a thermometer will indicate that the tumbler with the black paper is heated the most, and that with the silver paper the least, and yet all these vessels have been equally exposed to the rays of the sun. This difference is explained on the principle, that the sun's rays are reflected from light-coloured and shining bodies, whilst they are absorbed by those which have a dull, dark colour. From this absorption it would seem that the light of the sun's rays is converted into heat. It explains why black clothes keep us warmer than white ones; why the snow melts more rapidly when soot or dark earth is scattered upon it; and why grapes and other fruits ripen quicker against dark walls than against those having a light colour.

If hot water is poured into the tumblers enveloped with paper, and the cooling of it noted by the thermometer, the contrary effect will be observed; the glass covered with black paper will first become cold; and that wrapped in silver paper the last; because bodies with dull surfaces radiate the heat more rapidly than those with polished surfaces. For this reason, coffee retains heat longer in a bright than in a tarnished pot; a stove of glazed Dutch tiles remains hot longer than another of unglazed tiles; a smooth sheet-iron stove, longer than a similar one of rough cast-iron, &c.

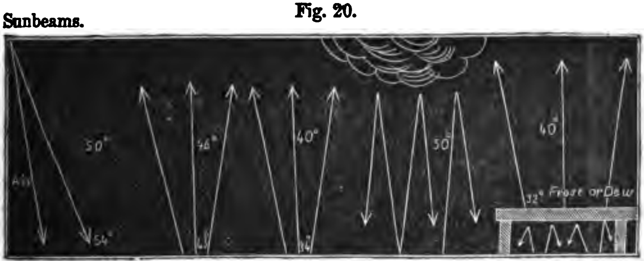
The radiation of heat enables us to explain some of those common natural phenomena which otherwise would remain obscure. Why do not the rays of the sun, even in the hottest summers, melt the snow upon the tops of high mountains, which are nearer than the level portions of the earth to the sun? Because they only heat those bodies which can absorb their warmth, as the rough surface of the earth. The snow is indeed struck by the rays of the sun, but being a white and shining body it reflects them and remains cold.

44. *Formation of Dew.*—When the surface of the earth has become warm, the air is heated by it; hence, during the day the lower strata will always be warmer than the upper. But a change takes place after the sun has gone down. The earth continues to radiate heat without receiving any in exchange, and its temperature consequently diminishes. On the other hand, the air does not so readily part with its heat, and therefore it retains during the night a higher temperature than the surface of the earth; it is only cooled where it comes in contact with the colder earth. If this cooling should reach the dew-point of the air (§ 38), then the vapours are condensed, on the soil or on the plants growing upon it, in the form of small drops, just as a tumbler is covered with vapour when brought from a cold into a warm room,—dew forms. If the temperature of the earth sinks in

the night to the freezing point, or below it, the aqueous vapour is deposited in a solid form, and is called *hoar-frost*.

The radiation of heat from the earth is greatest when the weather is clear and serene, but it is obstructed by clouds and wind. Hence the most copious deposit of dew takes place only in clear and quiet nights. The clouds serve as a screen in reflecting back the rays of heat to the earth, so that it is but slightly cooled. The same effect is produced by the mats, straw, and boards with which the gardener covers his young plants, to protect them from the late frosts of spring, or from freezing. The annexed figure, in which arrows denote the direction of the rays of heat, will serve to render this process more intelligible.

Fig. 20.



Surface of the earth. 59°	41° Dew.	0° Frost.	54° No dew or frost.	41° No dew or frost.
In the daytime.	In clear and serene nights.		Cloudy or windy nights.	Clear nights. Soil protected.

SOLUTION AND CRYSTALLISATION.

45. *Solution.*—Water can dissolve many bodies, and unite intimately with them, without losing its transparency. Such combinations are called solutions. If rain-water meets with soluble substances, either in the earth or in the rocks through which it oozes, it dissolves them; and this explains why almost all spring-water, on evaporation, yields an earthy or saline residue. Frequently this residue, particularly when it contains lime, is so altered during evaporation, that it can no longer be dissolved in water, and forms a hard incrustation round the inner sides of the vessels used in cookery. The springs of Carlsbad deposit so much residue, that articles immersed in them appear in a short time to be externally

petrified or incrusted. If water is unusually rich in soluble substances, especially such as possess medicinal properties, as, for example, iron, sulphur, &c., it is called *mineral water*, and the springs from which it issues are called mineral springs. A pound of sea water contains about half an ounce of substances in solution.

46. *Experiment.*—Pour a teaspoonful of slaked lime (§ 33) into a bottle, and fill it with water; cork it up, and, after shaking it for some minutes, let it stand until the water has become perfectly clear. By carefully inclining the bottle, most of the liquid may be poured off free from the sediment. This operation is called *decantation*, and the clear liquid is *lime-water*. Lime is but slightly soluble in water, three hundred ounces of water being required to dissolve half an ounce of lime; the excess remains undissolved, and as lime is heavier than water, it settles at the bottom. That a portion of it has been dissolved is known by the peculiar taste imparted to the liquid. This taste is called *alkaline*.

Keep a part of the lime-water in a well-stopped bottle for future use; it will remain transparent and clear. Pour the remainder into a tumbler, and expose it to the air; the water soon becomes turbid, and covered with a film, which gradually grows thicker, and settles at the bottom. When, after some days, the water has become clear again, it will have lost its alkaline taste; the lime dissolved in it, having been chemically changed by the air and rendered insoluble, will be found as a powder at the bottom of the tumbler.

47. *Experiment.*—Put into a flask half an ounce of litmus; pour over it three ounces of water, and let it remain in a warm place until the liquid has obtained a dark-blue colour. Litmus consists of a blue colouring-matter, which is soluble in water, and is hence taken up by it; it also contains some earthy matter, which is insoluble, and is deposited as a slimy mass. These two substances might be separated from each other, as in the former experiment, by decantation, but it can be done more readily

Fig. 21.

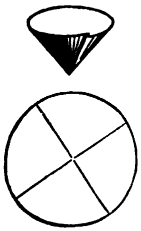
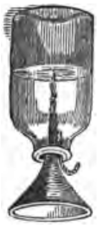


Fig. 22.



by *filtration*. For this purpose cut a piece of blotting-paper into a circular shape, fold it together twice, and then place this filter into a glass funnel. That the paper and the glass may not come into too close contact, place between them thin pieces of wood or glass; a piece of string must also be inserted between the funnel and the neck of the flask into which the liquid is to be filtered, to allow an opening for the escape of the air from the flask, as otherwise the fluid could not flow in. The filter, which must never be higher than the top of the funnel, is first moistened with water before the fluid is poured upon it. Blotting-paper consists of fine linen or cotton-fibres matted together, between which are small interstices or pores, through which liquids, but no fine solid particles, can pass; these remain on the filter. Writing-paper cannot be used for filtration, as its pores are filled up by size or starch.

48. *Experiment.*—Pour a part of the solution obtained into a saucer, and pass strips of fine blotting or of letter-paper one or more times through it, until they have acquired a distinct blue colour. Preserve these strips, after being dried, in a box; they are called blue litmus, or test-paper; they are reddened by vinegar, lemon-juice, and all acid fluids, and serve to test a liquid, to ascertain whether it is *acid* (has an acid reaction).

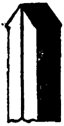
Experiment.—Mix cautiously another portion of the solution with lemon-juice, until the blue colour appears distinctly red; this also serves to colour paper. The red test-paper is used for the purpose of recognising a class of substances opposed to acids—that is, alkaline or basic bodies; these restore the original blue colour of the paper, as can be seen by bringing it into contact with lime-water or moistened ashes.

49. *Experiment.*—Add gradually, with constant agitation, to one ounce of cold water, powdered saltpetre, as long as it continues to be dissolved—perhaps about a quarter of an ounce; if more is added than is necessary, it will remain undissolved at the bottom of the vessel. This solution is called a *cold saturated* solution. If this mixture be boiled, and saltpetre again be added, then about two ounces more will be required to saturate the water. A thermometer held in this *boiling saturated* solution will indicate about 226° F. (108° C.), while simple boiling water indicates only 212° F. (100° C.)

All saline solutions boil and freeze with more difficulty than water. All bodies soluble in water behave in a similar manner,—that is, they are soluble in it only in definite quantities, and in most cases hot water dissolves more of them than cold.

50. *Experiment.*—If the solution obtained in the last experiment be poured into a porcelain dish, previously heated, and be suffered to remain quiet until cold, then the two ounces of saltpetre which were last added separate again, not as a powder, but as regularly formed prisms. These prisms are six-sided, and are surmounted by two faces similar to a roof; they are called *crystals of saltpetre.* (Fig. 23.) All crystals are characterised by having planes, edges, and angles, constructed, as it were, of simple triangular, quadrangular, or poly-angular pieces, artificially polished. This symmetry is found even in the interior of them, as can easily be seen by holding a transparent crystal towards the light, and turning it slowly round; or breaking it, when the fragments will often exhibit the same regular form which characterised the whole crystal. Thus, in inanimate nature, a mysterious power exists, similar to that which compels the bees to construct their six-cornered cells, and the potato to produce its five-angled corolla and five stamens, and by which the smallest particles of bodies, called *atoms*, are forced to arrange themselves in a fixed order, assuming a regular shape. But this can only be accomplished by a body in its fluid or aeriform state, since *free motion* of the atoms is essential. Time also is required for this operation; hence crystals are always more regular the more slowly they are formed. Many of the splendid crystals which have been dug from the depths of the earth were, perhaps, thousands of years in forming.

Fig. 23.



51. *Experiment.*—Evaporate the liquid remaining above the crystals in the former experiment at a gentle heat, until a scum is formed on the surface, then remove it from the fire, and let the solution cool, *stirring it constantly* with a wooden stick. In this way, instead of crystals, a *powder of saltpetre* will be obtained.

The liquid just alluded to may be regarded as a cold saturated solution, containing about a quarter of an ounce of saltpetre. If, by evaporation only, so much water is left as is sufficient when hot to keep in solution but a quarter of an ounce of the saltpetre, then crystals begin to appear in the form of a film on the cooler surface, indicating the saturation of the liquid. If this again is allowed to cool quietly, a second crop of crystals will be obtained; but, by continual stirring, they are broken at the moment of their formation —by slow movement into a coarse, and by rapid movement into a fine powder. This may be called *interrupted crystallisation*. Sugar presents a similar example; the same syrup, which, if cooled quietly, yields sugar-candy, when stirred, yields common loaf-sugar.

52. *Experiment.*—Put into boiling water as much common salt as will dissolve, and let the solution cool; no crystals will form, because salt is as soluble in cold as in hot water. Now evaporate one-half of the solution over a spirit-lamp, and set aside the other half in a warm place; in the first case, mere irregular grains of salt will be obtained, but in the latter case, after some days, regular cubes of salt will be deposited.

53. *Experiment.*—Dissolve a spoonful of salt and one of saltpetre in lukewarm water, and put the solution in a warm place, that the water may gradually evaporate; the two salts, which are intimately mixed in the solution, will upon crystallisation separate completely from each other. The saltpetre separates into long prisms, containing no trace of the common salt, and the latter separates into cubes, entirely free from saltpetre. Thus the particles of salt and saltpetre did not attract each other; but, upon crystallising out of the solution, the *homogeneous* salts assumed separately a regular form, precisely as if one only of these two substances had been dissolved.

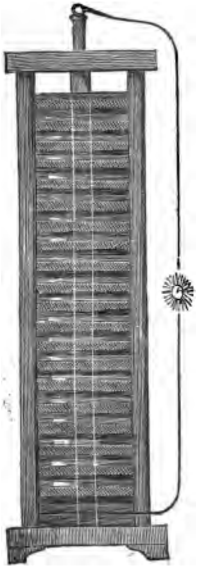
54. In our climate, water assumes a solid form during the winter only, and it is well known that, as snow or ice, it often forms the most regular crystals. But it also exists in a solid form in many bodies where we should not expect to find it: one pound of iron-rust, for example, contains nearly three ounces, and one pound of slaked lime four ounces, of water, and yet both are apparently dry. This water is said to be *chemically combined*. It also unites with other solid bodies, for which it has an affinity. Such combinations of solids with water are called *hydrates*. It is also frequently present

in salts, as can be shown in a simple manner in the case of the well-known Glauber salts.

Experiment.—Place half an ounce of crystallised Glauber salts in a warm place, when it will soon lose its transparency, and finally crumble into a white powder, weighing hardly a quarter of an ounce. That which has been lost was water, and it is evident that it was this water which gave to the salt its crystalline form and transparency, these both vanishing with the escape of the water. For this reason the water, on which depends the crystalline form of many salts, is called the *water of crystallisation*. Saltpetre and common salt, treated like Glauber salts, lose nothing in weight, neither do they become opaque nor pulverulent; they contain no chemically combined water.

COMPOSITION OF WATER.

Fig. 24.

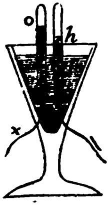


55. Besides that electricity, which we admire on a grand scale in the majestic phenomena of lightning, or which we generate on a small scale by rubbing various bodies together, a second kind of electricity is also recognised, which is called the galvanic force, or *galvanism*. This has attained great importance in chemistry, as, by means of it, the chemist is enabled to decompose almost all chemical combinations, even into their component parts or chemical elements. By galvanic force, water can easily be decomposed into its elementary parts. This sort of electricity may be generated in various ways; it is developed in every chemical combination or decomposition; indeed, very often even when heterogeneous substances, whether solid, liquid, or aeriform, are brought into contact. The oldest and most common galvanic apparatus is the *voltaic pile*, in which electricity is excited by the contact of two different metals, commonly zinc and copper. A copper plate placed

upon one of zinc is called a pair of plates; many such pairs are laid, one above the other, each pair being separated by a piece of cloth moistened with salt water. The relative position of the metals in each pair must be observed throughout the whole series, so that, if the pile commences with a zinc plate, it shall terminate with a copper one. These two extremities are called the poles. Zinc is called the + pole, and copper the — pole; they are provided with metallic wires, that the electric or galvanic stream which is excited in the pile may be conveyed to any place desired. When the two ends of the wires are brought very near to each other, sparks are seen to dart from one to the other; this is a token of the galvanic current, manifesting itself in the same manner as the current of the electrical machine.

To decompose water by means of this pile, the two wires, to the ends of which pieces of platinum-wire or foil has been fastened, are conducted into a vessel of water, and two test-tubes, filled with water, are inverted one over each wire; small bubbles of air are then evolved from the ends of both wires, which ascend into the test-tubes, gradually displacing the water from them. From the + or zinc wire, only half as much gas is generated as from the other; consequently the tube connected with the zinc will only be half emptied by the time the water from the other is entirely expelled, and a glowing shaving introduced into it will burst into a brilliant flame; it is called *oxygen gas (O)*. The gas evolved from the — or copper end, on the contrary, extinguishes this shaving; but the gas will burn spontaneously if kindled by the flame of a candle held over it;—it is called *hydrogen gas (H)*. These are the component parts of water; it consists of one measure (volume) of oxygen, and of two measures of hydrogen. From one measure of water, when decomposed into its elements, several thousand measures of these two gases may be obtained.

Fig. 25.



NON-METALLIC ELEMENTS, OR METALLOIDS.

FIRST GROUP: ORGANOGENS.

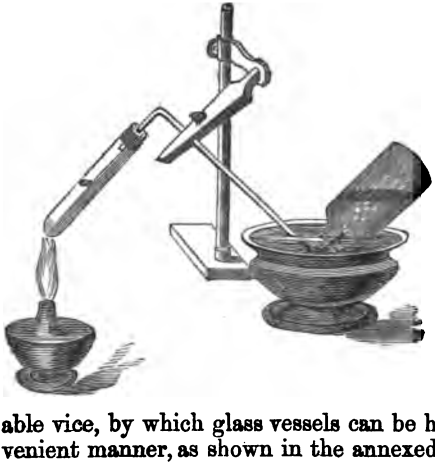
OXYGEN (O).

At. Wt. = 8.—Sp. Gr. = 1.1.

56. **Oxygen** may be obtained in great quantities from water, by means of the galvanic battery; but in a more simple manner as follows:

Experiment.—Introduce into a somewhat tall, but not too thin, test-tube, 109 grains of red oxide of mercury. One end of a bent glass tube is adapted to it by means of a perforated cork, and the other end is conducted into a vessel filled with water. Either suspend the tube by means of a piece of string or wire, or support it by a retort-holder. A retort-holder is a wooden stand, provided with a movable vice, by which glass vessels can be held in the most convenient manner, as shown in the annexed figure. Then heat the test-tube until all the oxide of mercury has disappeared. The red powder becomes black as the heat increases, and bubbles of air escape, which are collected in a glass bottle held over the end of the tube, this bottle having been previously filled with water and then inverted into the bowl, after closing the mouth of it with the finger or a glass plate. No water will escape until bubbles of air from the tube are passed into it, which, on account of their greater lightness, ascend and displace the water. When the water is displaced,

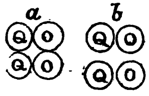
Fig. 26.



remove the bottle and close it with a cork, replacing it by another bottle, likewise previously filled with water, and repeat this process until the evolution of gas ceases. The first bubbles that pass over consist of the atmospheric air contained in the test-tube, and expanded by the heat, but the *oxygen gas* quickly succeeds. This is *one* of the component parts of the red oxide of mercury, and can easily be recognised by the vivid combustion in it of a glowing shaving. At the same time there is formed on the upper part of the test-tube a brilliant metallic mirror, which consists of mercury, the *second* element of the red oxide. When the latter has entirely disappeared, *immediately* withdraw the tube from the water, let the test-tube cool, and unite the mercury adhering to its sides into a single globule, by means of a feather. It will amount in weight to 101 grains; this, subtracted from the original weight, 109 grains, leaves 8 grains, the amount of the oxygen. The red powder consists of a brilliant heavy metal and of a gas, two entirely dissimilar bodies. If these are chemically combined together by proper means, they will unite again and form the red oxide, a body in which the peculiar properties of the mercury as well as of the oxygen are entirely lost.

57. This experiment shows, also, how the force of heat alone can annihilate chemical combination, or, in other words, the affinity of two bodies for each other. This can be explained as follows. Chemical affinity acts only at *imperceptible distances*, consequently only when bodies are in closest contact; heat counteracts this power, for it exerts an expansive action, and consequently separates the constituent particles from each other. In the cold, or at ordinary temperatures, the single particles of the quicksilver (Q) and oxygen (O) are so closely united, that chemical force is sufficient to hold them together (*a*, Fig. 27); but at an increased temperature they are so far separated (*b*), that the influence of chemical attraction is overcome. This occurs so much the more readily in this instance, as both the quicksilver and oxygen, when heated, have a strong tendency to become aeriform, which also tends to counteract the chemical force.

Fig. 27.



58. The bottles containing the oxygen appear to be empty, for oxygen is as colourless and invisible as common air, and is without odour or taste.

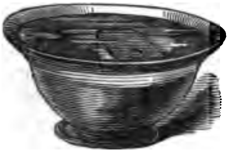
Experiment.—Introduce a glowing shaving into a bottle of oxygen; it will kindle and burn for some time with great brilliancy and a very dazzling flame, and then be extinguished. The same takes place when a piece of lighted tinder is fastened to a wire and suspended in the oxygen; the tinder burns with a lively flame, while, as is well known, it merely smoulders away in the open air. Oxygen possesses, at a high temperature, a strong affinity for the component parts of wood and tinder; that is, it combines with them with great energy, and consequently with the development of heat and light. When the combination has ended, and the oxygen is consumed, the combustion ceases. The product of the combustion, that is, the combination of the wood with the oxygen, is also aeriform; but burning substances are extinguished in the newly formed gas. If the bottle be rapidly whirled round, the gas formed by the combustion will escape, and atmospheric air will supply its place. Air contains free oxygen; and a kindled shaving will burn in it for some time, but far slower and less briskly than in pure oxygen; because common air contains only one-fifth part of oxygen. Accordingly, combustion proceeds five times more rapidly and violently in oxygen than in atmospheric air.

59. *Experiment.*—To prepare a larger quantity of oxygen, take one hundred grains of *chlorate of potassa*, and heat it in the same manner as described in the former experiment; the salt will soon melt, and afterwards boil. As soon as the boiling commences, the flame must be diminished, to prevent the mass from foaming over. When the liquid thickens, if some of the substance should be found adherent to the colder parts of the test-tube, approach it with the flame of the lamp until it is again melted down. As soon as the gas ceases to be generated, draw the tube *immediately* from the water. If you mix, by merely rubbing together with the fingers upon a sheet of paper, chlorate of potassa with its own weight of black oxide of manganese, the evolution of gas will be vastly accelerated.

60. For collecting gases in larger quantities, the following

contrivance may be resorted to. Make a shelf out of slate or a piece of lead, some inches broad, and so long that it will rest about half way up the sloping walls of the vessel in which it is to be placed; bore a small hole through the centre of the shelf with some appropriate instrument. When wanted for use, pour into the vessel as much water as will be sufficient to cover the shelf an inch deep, and then invert the vessel intended for the reception of the gas, with its mouth exactly over the opening, placing the extremity of the glass tube, from which the gas proceeds, directly beneath, so that the gas may enter it as through a funnel. This contrivance is called a *pneumatic trough*. In order to collect and preserve larger quantities of gas, and to experiment with them more conveniently, special contrivances, called *gasometers*, are used in chemical laboratories.

Fig. 28.



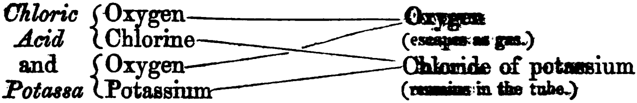
61. Chlorate of potassa contains for every one hundred grains about forty grains of oxygen chemically combined; by the application of heat, these become free and escape. Red oxide of mercury contains only eight per cent. of oxygen; therefore the former will yield five times more oxygen than the latter. If vials of twelve ounces' capacity are selected for receiving the gas, we shall be able to fill five of them, and shall have in each about eight grains, or nearly twenty cubic inches, of oxygen.

Chlorate of potassa may, under some circumstances, as when strongly rubbed, or treated with sulphuric acid, occasion *very dangerous explosions;* but no danger is to be apprehended from the application of it in the manner above directed.

62. *Experiment.*—Add warm water to the salt remaining in the test-tube after the expulsion of the oxygen, and place the tube in a warm place until the salt is dissolved; evaporate the solution gradually, over a stove, when small cubic crystals (chloride of potassium) will be deposited. The chlorate of potassa crystallises in thin tables or plates, the heated mass in cubes; this difference in the form of the crystals alone indicates that, by the heating of the former, an entirely new salt is formed, and one, indeed, which no longer

contains oxygen. The following diagram will illustrate this more clearly.

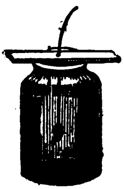
Chlorate of Potassa consists of



Experiments with Oxygen.

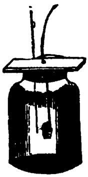
63. *Experiment a.*—Fasten a piece of charcoal to a wire, and kindle it in the flame of a lamp, and then introduce it into a bottle of oxygen; it will burn very vividly, and with a flame. If a piece of moistened blue litmus-paper (§ 48) be introduced into the bottle, after the combustion, it will be reddened; consequently an acid gas has been formed from the charcoal and the oxygen; it is called *carbonic acid.* Close the flask, shake it a few times, and place it aside.

Fig. 29.



64. *Experiment b.*—If some pieces of sulphur are fastened to a longer wire, kindled and suspended in a second bottle, they will burn with a beautiful blue flame. The gas formed from this union of sulphur and oxygen has a very irritating odour; it likewise turns litmus-paper red, and consequently it is of an acid nature. It is called *sulphurous acid.* This bottle is also closed and preserved for future use.

Fig. 30.



65. *Experiment c.*—Take a small piece of phosphorus, which, on account of its inflammability, must be cut off under water from the stick, and place it, after having been *well dried* between blotting-paper, in a scooped-out piece of chalk. Fasten the latter to a wire, and introduce it into a third bottle of oxygen. Affix the wire to a cross piece of wood, so that the chalk may hang a little below the centre of the bottle. If the phosphorus be now touched with a hot wire, it will kindle and burn with a dazzling brilliancy, filling the bottle with a thick white smoke. This smoke consists of a chemical combination of oxygen and phosphorus; it reddens the blue test-paper, consequently is also an *acid;* it is called *phosphoric acid.* If the bottle be allowed to stand for a time, the smoke

will sink to the bottom, and dissolve in the water previously put there, which thus acquires an acid taste.

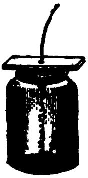
66. In the same way as the tasteless charcoal and the tasteless sulphur and the phosphorus, by combination with oxygen, acquire acid properties, so many other simple bodies are converted by oxygen into *acids;* this is the reason why it has received the name of *oxygen*, derived from two Greek words, one of which signifies *acid*, and the other *to generate*. Thence the words *oxidate* and *oxide*, so frequently occurring in chemistry. *Oxidate* signifies to unite with oxygen, to burn; *oxide* is the product of the combination, and signifies a burnt substance, that is, a substance combined with oxygen. The acids just alluded to may also be called *acid oxides*.

Fig. 31.

67. *Experiment d.*—Fix securely to a wire a piece of sodium, and let it remain for some hours in a bottle filled with oxygen; it becomes converted into a white mass, which easily dissolves in water. The solution obtained has an alkaline taste, similar to lime-water; the colour of blue test-paper is not changed by it, but it turns red test-paper *blue;* this is a combination which may be regarded as the opposite of acids; it is called *oxide of sodium*. Let this also be kept for future use.

The metal *sodium* has such an extraordinary affinity for oxygen, that it quickly attracts it from the air. Therefore, to preserve it unchanged, it must be kept in some liquid containing no oxygen; as, for instance, in naphtha or petroleum.

Fig. 32.



68. *Experiment e.*—A piece of fine iron wire is so wound round a slate- or common lead-pencil, that, on the withdrawal of the latter, the wire may have a spiral form. Fasten the upper part of this wire, as in experiment *c*, to a cross-piece of wood, and place on the lower end of it a small portion of tinder. When this is kindled, introduce the wire into the oxygen; the burning tinder heats the iron to redness, which then burns brilliantly, throwing out sparks. The iron, when red-hot, combines with the oxygen. The burnt or oxidised iron (iron scales) melts, and falls to the bottom in

globules, which are so hot that they are liable to melt into the glass, though it be partly filled with water. This heat, as in the preceding case, is the result of chemical combination taking place. Oxide of iron is insoluble in water, and for this reason it affects the colour neither of the blue nor of the red test-paper; if it were soluble, it would, like oxide of sodium, convert the red into blue paper.

69. Such combinations of oxygen as are not acid, but agree in their properties with the oxide of sodium or of iron, are called *bases* or *basic oxides*. Most of the combinations of the *metals* with oxygen belong to the bases.

70. From the foregoing experiments on oxidation, the question arises—How much carbon, sulphur, &c., have the eight grains of oxygen contained in each bottle consumed or taken up? The reply is—They have taken up very different quantities.

They have united as follows:

8	grs. of oxygen	with	3	grs. of	carbon,	forming	11	grs. of	carbonic acid.
8	"	"	8	"	sulphur,	"	16	"	sulphurous acid.
8	"	"	6½	"	phosphorus,	"	14½	"	phosphoric acid.
8	"	"	23	"	sodium,	"	31	"	oxide of sodium.
8	"	"	20	"	iron,	"	28	"	black oxide of iron.
8	"	"	1	"	hydrogen,	"	9	"	oxide of hydrogen (water).

Carbonic acid may be prepared in different ways, but it is always so constituted as to contain eight grains of oxygen united with three grains of carbon, and this same regularity exists in all the above compounds, as indeed in all chemical combinations. It is a law of nature; *chemical combinations always take place according to certain fixed proportions by measure and weight.* This doctrine is called the doctrine of definite proportionals, or Stoichiometry (from στοιχεῖον, element, and μέτρον, measure).

71. *Experiment.*—The liquid in the vessel *c* reddened blue test-paper, and had a sour taste; the liquid in the vessel *d*, on the contrary, turned the red paper blue, and had an alkaline taste. Add the latter slowly, and at last only by drops, to the former, testing the mixture frequently with a strip of blue and red test-paper; there will be a point when the colour of these two papers will no longer be changed. The acid and alkaline tastes have likewise disappeared, and the mixture has acquired a slightly saline taste; it is *neutral.*

The phosphoric acid has chemically combined with the oxide of sodium, forming a new body having no similarity to either of the substances of which it was composed. To obtain better knowledge of it, let the vessel remain in a warm place until the water has evaporated, when small crystals will be deposited. Such a combination, consisting of an acid and a base, is called a *salt*. This salt, phosphate of soda, is called *soluble*, because it assumes a liquid form upon the addition of water.

72. *Experiment.*—Pour into the bottle which contained the carbonic acid gas (experiment 63) some lime-water (§ 46), and agitate it; the liquid will become milky, and after standing, a white powder will subside. The lime in the lime-water is a base, as well as the oxide of sodium; the lime combines with carbonic acid, they mutually neutralising each other; but the salt which is formed (carbonate of lime or artificial chalk) is *insoluble* in water, and hence separates from it. That the carbonic acid here disappears, and is condensed into a solid body, is indicated by the suction exerted upon the finger with which the mouth of the bottle was closed during the shaking, and the rushing in of air after its removal.

73. *Experiment.*—Exactly the same thing occurs when lime-water is poured into the bottle of experiment 64; the irritating odour of the sulphurous acid contained in it vanishes, owing to the latter combining with the lime. The salt formed (sulphite of lime) is very *difficultly soluble* in water.

74. *Experiment.*—Pour gradually into the bottle of experiment 68 one dram of common sulphuric acid. It heats, becomes hot, and unites with the water; and, after repose and frequent agitation, the red oxide of iron which collects on the sides of the vessel, as well as the black oxide of iron at the bottom, will dissolve. In this case, also, a salt is formed, since the base (oxide of iron) has united chemically with the acid; the yellowish liquid holds the *iron salt* in solution.

75. *Degrees of Oxidation.*—Oxygen is a universal food for all elements; it is consumed by them, and, as already stated, in fixed proportions or quantities. But the appetite of an element for oxygen often varies according to the circum-

stances under which the latter is presented to it; for example, it is greater under the influence of heat than of cold —greater where there is an excess than where there is a deficiency of oxygen. Hence many elements frequently consume greater quantities of it at a high than at a low temperature, and when the supply is copious than when it is deficient; and this excess or diminution of consumption is likewise prescribed by fixed laws. The different proportions in which substances unite with oxygen are called its *degrees of oxidation.*

76.—When sulphur is burnt in oxygen gas, or in the air, it combines with oxygen, forming *sulphurous acid;* but it can be made to unite with one half as much more oxygen, and then *sulphuric acid* is formed.

When phosphorus is rapidly burnt, it forms with oxygen *phosphoric acid;* but if it be exposed to the air without the application of heat, or be burnt with imperfect access of air, then *phosphorous* acid is principally formed, which contains two-fifths less oxygen than phosphoric acid.

Accordingly, by the terms sulphur*ic* and phosphor*ic* acids, are to be understood combinations with *more* oxygen; by the terms sulphur*ous* and phosphor*ous* acids, combinations with *less* oxygen. If an element yields more than two acids with oxygen, then new names are formed by prefixing to the acids the terms *per* or *hypo;* for instance, perchloric acid, hyposulphuric and hyposulphurous acids, &c.

77. Besides the red oxide or peroxide of quicksilver (§ 56) there is yet another combination of quicksilver with oxygen, which is black, and contains only half as much oxygen as the former; it is called the protoxide of quicksilver. Iron also forms two combinations with oxygen; one of a reddish-brown colour (sesquioxide of iron), and the other of a black colour, containing one third less oxygen (protoxide of iron). Accordingly a *peroxide* or a *sesquioxide* is the combination of a metal with a greater quantity of oxygen, and a *protoxide* is a combination with a less quantity of oxygen. Many metals have the power of uniting in more than these two proportions with oxygen; in this case, the combination with a less quantity of oxygen than in the protoxide is called *suboxide,* but that with more oxygen than in the per- or sesqui-oxide, is called *superoxide* or *hyperoxide.* Neither the lower nor

the higher oxides act as bases, that is, they will not unite directly with acids to form salts; but, nevertheless, this may happen when the suboxide receives so much oxygen, or the superoxide parts with so much, as to form, in either case, per- or sesqui-oxides or protoxides. Some metals in their highest state of oxidation possess no longer basic properties, but, on the contrary, acid properties *(metallic acids)*.

(In other countries than Germany, the term peroxide is generally applied to the compound containing most oxygen, but not possessing acid properties.)

78. If we compare the different quantities of oxygen which one and the same body can take up, they will always be found in very simple proportions; for instance:

In	sulphurous and sulphuric acids,	as	2 to 3.
"	phosphorous and phosphoric acids,	"	3 to 5.
"	protoxide and peroxide of mercury,	"	1 to 2.
"	protoxide and sesquioxide of iron	"	2 to 3.

A similar regularity exists in all other chemical combinations.

79. The *superoxides* easily give up a part of their oxygen, either when heated alone or with certain acids; hence they can be made use of for obtaining oxygen. A hyper- or superoxide of frequent occurrence in nature is that generally called the *peroxide of manganese*, used for colouring potters' ware brown. It is a combination of the metal manganese with oxygen. Oxygen is usually obtained from this when wanted in large quantities, as it can be put in an iron vessel and heated to a bright redness. If the manganese is heated alone, one third of the oxygen contained in it is obtained, and red oxide of manganese remains behind; but if heated with the addition of sulphuric acid, one half of its oxygen is obtained, and the remainder is protoxide of manganese, which combines with the sulphuric acid, forming a salt.

80. Oxygen is absolutely necessary to all living creatures. All the air which we breathe must contain free oxygen; if this is wanting, suffocation is induced. The chemists, who discovered it seventy years ago, and first prepared it pure, gave to it, for this reason, the name of *vital air*. In later times it was designated *empyreal air*, because it was found that every combustion, however familiar to us, was a process of oxidation, in which the oxygen of the air combined with the particles of the burning material. The symbol for oxygen

is O, the *first letter* of oxygen. It has been agreed to express simple bodies by the first letters of their Latin names; when more than one commence with the same letter, another is added to the former.

HYDROGEN (H).

At. Wt. = 1.—Sp. Gr. = 0.068.

81. *Experiment.*—Boil some water for fifteen minutes, that all the air contained in it may be expelled; let it cool, and fill a bowl and a test-tube with it; close the latter with the finger, and invert it under the water in the bowl. Now fasten to a wire a piece of sodium, of the size of a lentil, and thrust it quickly under the opening of the test-tube; the metal frees itself from the wire, and, as it is lighter than water, it ascends into the tube, floating there with a circuitous motion; a gas is evolved from the water, which in a few moments displaces the latter from the tube. This kind of gas is the second element of water, and is called *hydrogen*. The experiment in § 67 demonstrates that sodium has a very great affinity for oxygen, and this affinity is so strong, that the sodium removes from the water its oxygen, whereby the hydrogen is liberated. Close the tube again with the finger, remove the tube from the vessel, and hold a burning taper over it, when the gas will burn with a flame. Hydrogen is a *combustible* gas. If the interior of the moist-tube be tested with a strip of red test-paper, this assumes a blue colour. The same base, oxide of sodium, has been formed as when the sodium was exposed to oxygen or to the air. It is dissolved by the water.

Fig. 33.

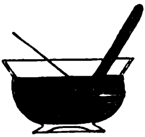
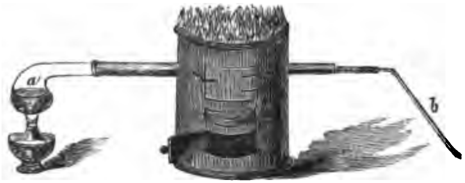


Fig. 34.



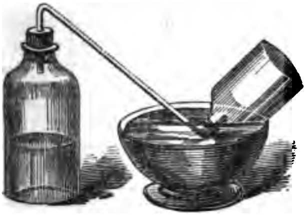
82. What sodium accomplishes at ordinary temperatures, iron cannot do until it is heated to redness. Pass water in the form of steam, obtained by boiling the water in the retort, *a* (Fig. 34), through a red-hot iron pipe, as a gun-barrel, containing iron wire spirally

coiled. At this high temperature the iron in the pipe unites with the oxygen in the water, forming black oxide of iron, and the hydrogen is set free, and may be collected. This is the method by which the celebrated French chemist, Lavoisier, sixty years ago, proved that water is not a simple body, but consists of two gases, oxygen and hydrogen.

83. The decomposition of water by iron is more easily effected through the presence of an ally, which supports the iron in its endeavour to extricate the oxygen from the water. Such an ally is sulphuric acid.

Experiment.—Put a quarter of an ounce of wrought-iron filings into a flask, and pour over them two and a half ounces of water. No action takes place, but if half an ounce of common sulphuric acid be gradually added, at the same time keeping the flask in constant motion, ebullition and heating of the liquid will immediately ensue. The ebullition is caused by the evolution of a species of gas, hydrogen. Insert into the opening of the flask a perforated cork, to which is fitted a bent glass tube. Allow the first portions of the gas to escape, then collect it, as the oxygen was collected, in a flask filled with water over the pneumatic trough.

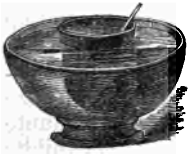
Fig. 35.



There is one indispensable caution to be observed in experimenting with hydrogen, which is, ***not to begin to collect the gas until all the atmospheric air existing in the flask has been expelled***, as otherwise an explosion might take place.

84. *Experiment.*—If sulphuric acid is poured into water, considerable heat is evolved; but this heat is much greater when the water is poured into the sulphuric acid. The mixture is best made in the following manner. Pour two ounces and a half of water into a sufficiently large stone jar, which is placed in a bowl filled with water; now weigh in a flask half an ounce of common sulphuric acid, pour this in a small stream into the water, stir-

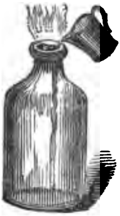
Fig. 36.



ring the water continuously with a glass or porcelain rod, and let the jar remain in the bowl until it is entirely cold. This mixture is called *diluted sulphuric acid;* the strong acid, on the contrary, is called *concentrated sulphuric acid.*

85. *Experiments with Hydrogen.*

Fig. 37.



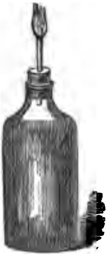
Experiment a.—Inflame hydrogen contained in a flask, and immediately pour in some water. The water does not extinguish the flame, but rather increases it, since it rapidly forces the gas out of the flask. The gas does not burn in the interior of the vessel, but only on the outside, where it is surrounded by atmospheric air.

Experiment b.—Hold an empty tumbler over a flask of hydrogen for some minutes, then quickly invert the tumbler, and apply to it a lighted taper, when a flame will burst forth from the tumbler with a whizzing noise. The gas has ascended from the flask into the tumbler, and is consequently *lighter* than common air. In this experiment the lower vessel must not be immediately exposed to the lighted taper, because, if all the hydrogen is not displaced, an explosion might ensue that would break the flask; but if the taper be applied aften ten minutes have elapsed, the flask will be found no longer to contain any combustible gas, this having entirely escaped.

Hydrogen is the *lightest* of all gases; 14½ measures of it weigh only as much as one measure of atmospheric air. On account of this lightness, it may be used for filling balloons.

Experiment c.—If, instead of the glass tube, a piece of tobacco-pipe be adapted to the cork of the flask from which hydrogen was evolved, and the gas then lighted, it will burn like a taper. To kindle the gas, instead of a match or a taper, very finely divided platinum may be employed. This can be prepared in a few minutes by dropping a solution of platinum on blotting-paper, attaching it to a wire, and igniting it over a spirit-lamp, till nothing but a grey coherent ash remains. The platinum is thus reduced to an extremely minute state of subdivision, and in this state it exhibits the remarkable property of igniting in hydrogen

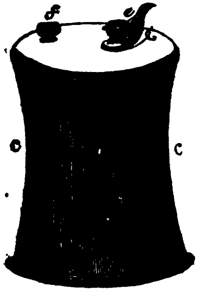
Fig. 38.



and inflaming it. It is called spongy platinum, and is employed as tinder in the well-known *Döbereiner's inflammable lamp.*

The apparatus here represented consists of a flask, having the bottom broken off, and to the neck of which the cover of the glass vessel, *c*, with the cock, *e*, is fastened air-tight. A piece of zinc is suspended in the flask by means of a wire. If diluted sulphuric acid is now poured into the vessel, *c*, upon which the cover with the flask attached is placed, then, the cock being opened, that the air contained in the flask may be displaced by the acid from beneath, hydrogen is immediately evolved by the contact of the zinc with the acid, which hydrogen must be collected in the flask by closing the cock, *e*, the acid being thereby forced into the exterior vessel, until it no longer touches the zinc. Upon opening the stop-cock, *e*, the gas issues from the fine jet, and is directed against the spongy platinum, *f*. As the gas escapes, the sulphuric acid passes again into the interior vessel, and generates fresh hydrogen upon reaching the zinc. Spongy platinum possesses, in a high degree, the power of absorbing oxygen and condensing it within its pores; if hydrogen be then presented to it, these two gases will be brought into such intimate contact, by the powerful force of attraction, that they will chemically combine to form water, and the heat thus liberated is sufficient to ignite the platinum tinder, and to inflame the gas, which subsequently issues from the jet. Many aeriform bodies, which do not freely unite with each other, can be forced to combine by means of spongy platinum.

Fig. 39.



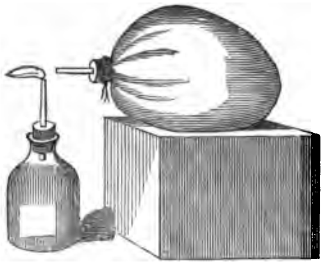
86. *Explosive Gas.*—The extraordinary degree of heat developed by the chemical union of oxygen and hydrogen may be shown by the following experiments. Insert into the opening of a large pig's bladder, which has been softened by soaking in water, the broken-off neck of a flask, and bind it firmly round with a string. Then select two perforated corks, fitting this neck. One cork is connected with a bent glass tube, conducting the oxygen from the apparatus in which it is evolved (§ 59) into the bladder, which soon becomes filled with it. When this operation is finished, re-

place the first cork by the second, having a glass tube adapted to it only a few inches long and drawn out to a point at its outer end, and provided with a wax stopple pressed upon the opening. A glass tube may be formed into a point by heating it in the flame of a spirit-lamp, constantly turning it round at the same time, till it becomes so soft at the desired place as to be easily drawn out. Break it at the slender part, and hold it in the flame for some moments, until the sharp edges are rounded off by incipient melting. It would be more convenient, though somewhat more expensive, to substitute for the above contrivance a small brass stopcock, provided with a jet.

Fig. 40.

The bladder thus arranged and filled with oxygen is now placed upon a block, at such a height that the point of the glass tube shall be on a level with the hydrogen flame, produced as explained in a former experiment. Press upon the bladder with the hand, and the oxygen will escape, blowing into the hydrogen flame, which then takes a horizontal direction. This flame has but little brilliancy, less than the hydrogen flame alone, notwithstanding which it affords the greatest heat yet known. Hold in it a platinum wire, a metal which has never yet been melted in the hottest furnace, and it will melt like wax; hold in it a piece of chalk scraped to a fine point, and it will emit light (sidereal light) of the most dazzling splendour. A watch-spring or a fine iron wire burns in it, throwing out sparks as in oxygen. (§ 68.) But what is the cause of this powerful heat?—It is the result of the energetic chemical combination of two substances with each other. *Every chemical combination or decomposition is attended with liberation of heat.*

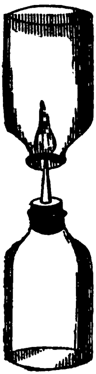
Fig. 41.



Exact experiments have shown that two measures of hydrogen unite with one measure of oxygen, consequently in just the same quantities as obtained in the decomposition of water by galvanism. (§ 55.) The result of the combination is water. But two measures of hydrogen and one of oxygen do not yield three measures of vapour; they afford two measures only. Thus the two gases condense one-third by chemical union. If both the hydrogen and oxygen were suddenly mixed together and then ignited, the whole mass would combine together at once, producing a most violent report, and bursting the vessel to pieces. Such a gaseous mixture is called, for this reason, *explosive gas*. No danger is to be apprehended from the apparatus described, as the explosive gas is formed at the point where the oxygen meets the hydrogen flame, and only in small quantities at once. This apparatus is an oxy-hydrogen blowpipe on a small scale. Hence explosive gas may be regarded as chemically decomposed water, and water as chemically combined explosive gas, or as burnt hydrogen.

87. *Experiment.*—That water is really formed during the combustion of oxygen and hydrogen, or when they chemically unite, can easily be shown by inverting a flask over the hydrogen flame; the glass soon becomes clouded over, because the water, which at this heat is generated in the form of steam, condenses in small globules on the cold sides of the glass. By this method one full measure of water has been obtained from one thousand measures of oxygen and two thousand measures of hydrogen.

Fig. 42.



By the decomposition of water (*analysis*), and by combining together its elements (*synthesis*), it is proved to consist, in *volume*, of one measure of oxygen and two measures of hydrogen, yielding two measures of vapour; in *weight*, of eight parts of oxygen and one part of hydrogen, yielding nine parts in weight of water.

The great difference between the numbers of the measures and those of the weight depends on the fact, that one measure of hydrogen weighs sixteen times less than one of oxygen. On account of the property possessed by hydrogen when combined with oxygen of forming water, the name *Hydrogen* (water generator) has been given to it; its chemical symbol is accordingly H.

88. *The chemical symbols*, which, as previously stated, are derived from the initials of the Latin names of the elements, present not only a very convenient and simple mode of designating the elements, but they represent also their *atomic weights*, which are given at the head of the different sections. Consequently O signifies not merely oxygen, but 8 parts by weight of it (pounds, ounces, grains, &c.); H, not only hydrogen, but also 1 proportion by weight of it. When two elements are in combination, this is designated by uniting together their symbols; $H\,O$, for instance, is the formula for water, and this indicates, not only that water consists of hydrogen and oxygen, but also that it is composed of 1 part by weight of hydrogen (1 At. H) and 8 parts of oxygen (1 At. O). In more complex combinations, the different members are separated from each other by a comma, or the sign +, as will be seen in the following sections. The smaller numbers in the formula placed *below* the letter modify only the symbol immediately preceding, but the larger numbers *prefixed* to the sign modify all the symbols as far as the next comma or + sign. H_2 signifies accordingly two atoms of hydrogen, H_3, three atoms, &c.; but $2\,H\,O$ indicates two atoms of hydrogen and two atoms of oxygen, &c. It is earnestly recommended to every beginner in chemistry to familiarise himself with this comprehensive language of symbols.

89. The change which iron underwent, when, by the aid of sulphuric acid, it decomposed water and liberated the hydrogen, remains now to be considered.

Experiment.—Pour the contents of the flask of experiment 83 into a porcelain dish, heat them to boiling, and filter them. A black residue will remain on the filter, which principally consists of carbon that was contained in the iron; the iron itself has been dissolved, and has passed through the filter; it is no longer iron as such, but has been converted into a salt of iron, which, on the cooling of the solution, is deposited in green, transparent crystals. The formation of it is explained in the following diagram:

Water = oxygen and hydrogen
Iron = oxide of iron
Sulphuric acid = salt of iron.

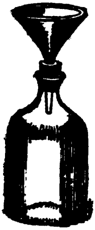
This salt is accordingly called sulphate of iron, commonly known as green vitriol. Iron and sulphuric acid cannot combine directly with each other, for it is a rule in inorganic chemistry, with but few exceptions, *that simple bodies unite only with simple bodies, and compound only with compound bodies;* however, this combination can take place when the iron is oxidised, and thus converted into a compound body. The water contains the oxygen requisite for this purpose, but the iron has not power enough to extricate it without the assistance of the sulphuric acid, which, having a strong affinity for a base, co-operates with it and enables it to overpower the water, and a base is formed (protoxide of iron) which immediately unites with the sulphuric acid. The liberated hydrogen escapes as gas. This sort of affinity is called predisposing affinity.

Zinc is frequently used instead of iron in the preparation of hydrogen.

AIR.

90. The earth is surrounded by air, as by a mantle; this mantle is called the *atmosphere,* and is supposed to extend about forty-five miles above the solid earth. The air possesses no colour, and is transparent; hence it is invisible, and its particles are so easily movable upon each other that it cannot be grasped by the hand. But it is rendered obvious that the air is material, and fills every space commonly called empty, by wrapping strips of moistened paper round a funnel, so that it may fit exactly into the mouth of a bottle; if the funnel be now filled with water, the fluid will *not* run into the bottle, as the air contained in the latter will not let it enter; but if the funnel be raised a little, the air escapes, and the water immediately rushes into the bottle. We learn also by the balance that a vessel apparently empty, *i.e.,* containing atmospheric air, weighs more than one which is really empty, as when the air has been exhausted from it. But air is so light that 800 measures of it weigh only as much as one measure of water, yet the atmosphere presses with great weight on the earth, and upon everything thereon. But this pressure is

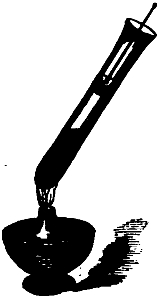
Fig. 43.



only noticed when the air is removed from a place, thus leaving it without counter-pressure.

91. *Pressure of the Atmosphere.*—*Experiment.*—Wrap some tow round one end of a stick, and grease it with tallow, thus forming a plug, which must fit tightly into a strong test-tube. Boil some water in the test-tube, and when the air has been expelled by the steam, causing a vacuum, insert the plug; as the water cools, the plug will be pressed down upon the surface of the water; by heating, it is again forced up by the steam thus generated, and by immersing in cold water it is again forced down. In consequence of the cooling and condensation of the steam a vacuum is formed, and, therefore, the counter-pressure against the weight of the exterior air is removed; the pressure of the latter, accordingly, forces down the plug. On this principle the piston is forced up and down in the cylinder of many steam-engines.

Fig. 44.



92. This one-sided pressure often causes the ascent and reflux of liquids in tubes.

Experiment.—If water is boiled as was directed at § 36, by means of steam, and during the boiling the lamp is removed, then the pressure of the air acting on the surface of the water in the beaker-glass will very soon force the water contained in it through the tube back into the flask, which in a short time becomes quite filled with water. The counter-pressure of the steam must naturally decrease as it cools and condenses. As long as the lamp is under the flask, the pressure of the steam is stronger

Fig. 45.

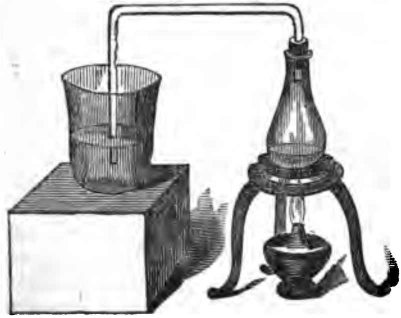
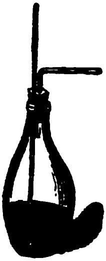
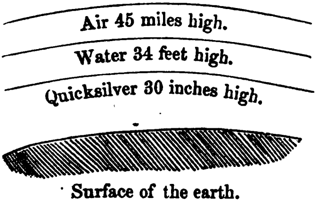


Fig. 46.



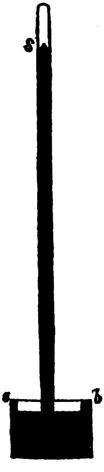
than that of the air, and the steam, being continually generated, forces the air previously contained in the flask into the water of the beaker-glass. This reflux of liquids is particularly to be feared, when such kinds of gases are conducted into water as are absorbed by it readily, and in large quantities. This is prevented by passing through the cork a second glass tube open at both ends, and letting it reach nearly to the bottom of the flask, by which tube air can penetrate into the flask as the pressure of the steam diminishes. This contrivance is called a *safety-tube.*

Fig. 47.



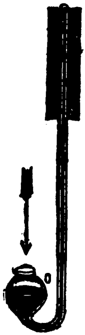
93. *Barometer.*—It has been proved by exact calculation that the atmosphere presses upon the earth with a force equal to that of a layer of quicksilver 30 inches deep, or a layer of water 13½ times deeper (34 feet), water being 13½ times lighter than quicksilver. The instrument by which the amount of atmospheric pressure can be observed and measured is called the *barometer.* Fill a glass tube, 32 inches in length, one end of which is closed, with quicksilver; close it with the finger, and invert it into a vessel of quicksilver; on removing the finger, the mercury will not run out, but will fall some inches, perhaps to *s* (Fig. 48). The height of the column of quicksilver, from *a b* to *s*, amounts to about 30 inches. The quicksilver does not fall lower, on account of the external pressure of the atmosphere, which is exerted on the quicksilver at *a b*, and not at *s*, since this end is closed. The column of quicksilver in the tube may be regarded as the counterpoise to the atmospheric pressure, and it is hence concluded that the latter exerts just as much pressure upon the earth as a column of quicksilver 30 inches high. If the tube be opened at the top, the pressure of the air on both ex-

Fig. 48.



tremities being then made equal, the quicksilver will flow from the tube. The space above the quicksilver, at *s*, is a vacuum, and is called the Torricellian vacuum, from the name of the inventor. In common barometers the tube is curved at the bottom, and provided with a bulb. This bulb is open at the top, and supplies the place of the vessel filled with quicksilver in the preceding figure. Here also the pressure is only exerted at one end, for the atmosphere can only press on the mercury contained in the bulb. The height from *o* (Fig. 49) to the top of the quicksilver amounts to about 30 inches.

Fig. 49.

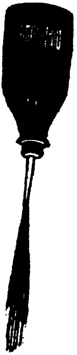


If weights be placed in one pan of a balance, the opposite one will rise, but on their removal it will sink. The same thing happens with the barometer. Any increase in the weight or density of the air presses the quicksilver up, and the barometer rises; but any diminution of weight will make it fall. The height of the quicksilver may be read off by fixing to the upper part of the tube a scale divided into inches and tenths of an inch. The mean state of the barometer is at 30 inches, and 31 is called a very high, and 29 a very low, state of the barometer. In this country, as a general rule, the north and east winds cause the barometer to rise, and the south and west winds cause it to fall. The former winds, blowing chiefly from the land, are cooler, and at the same time drier, than the latter, which pass over the ocean, there becoming saturated with moisture; the former likewise come from colder into warmer, while the latter, on the contrary, proceed from warmer into colder regions; by which the capacity of saturation for vapour is increased in one case and diminished in the other. Hence it is natural that, when north and east winds prevail, it should rain less frequently than during south and east winds; and that the former winds are dry, while the latter are damp. This is, perhaps, the principal reason why barometers are regarded as weather prophets.

Why water does not flow from a jar inverted over the pneumatic trough, why it continues to flow through a syphon after the air has been exhausted, why liquids will not run into a vessel when the air is confined, or why water will only rise to the height of 34 feet in a suction pump, are questions that scarcely require further explanation.

94. If the pressure or tension of a confined quantity of air be increased, by compressing it either directly or by the addition of more air, it can be forced to stream out from a small opening with great rapidity, as is shown on a small scale in the common bellows, and on a larger scale in the blacksmith's bellows. Should there be water before this opening, the air will press it out in a jet or stream.

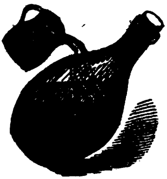
Fig. 50.



Experiment.—Take a piece of a fine glass tube, drawn out to a point, and adapt it, by means of a perforated cork, to a bottle. Fill the bottle half full of water, and blow into it through the point of the tube; when the blowing ceases, the air will escape in a stream. But if the bottle be inverted as soon as the air is blown in, then the water will be spurted out by the compressed air above. Such an apparatus (the washing-bottle) is frequently employed for washing residues or precipitates remaining on filters, in order to free them from soluble matter. There is a similar contrivance connected with the common fire-engine, called the air-vessel, enabling it to throw an uninterrupted stream of water.

95. *The pressure of the atmosphere* exerts a great influence *on the boiling* of water, and of other liquids. If water is made to boil when the quicksilver in the barometer is very low (in foul weather), brisk ebullition will take place at about 210° F. (99° C.); when the quicksilver is very high (in clear weather), boiling will not occur under 214° F. (101° C.)

Fig. 51.



Experiment.—Heat a flask half filled with water till the water boils briskly; then remove it from the fire and quickly cork it; the boiling immediately ceases, but will commence again if cold water be poured over the upper part of the flask. In this manner it can be made to bubble or boil, even though it be only lukewarm. There is no air in the flask, it having been expelled by the steam, and it could not re-enter it, on the cooling and condensation of the steam, on account of its having been closed. Consequently there is no pressure of air on the water, and it will boil even at a temperature of 68° F. (20° C.) The boiling ceased on account of the pressure of the steam upon the water; but the steam being condensed by the cold water, the pressure was so much diminished, that a portion of water again became aeriform with a boiling motion. In many manufactories, an appropriate apparatus (vacuum-pan) has been contrived for boiling and evaporating in a vacuum, as, for instance, in sugar-houses.

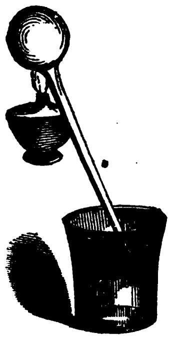
The air is densest at the level of the sea, and thinner in proportion to its distance from the earth, as there is less air above it. Hence the mercury will stand lower, and water boil more easily, on the top of a mountain than in the valley below. On the top of Mont Blanc quicksilver rises only to the height of 16 inches in the barometer, and water boils at 183° F. (84° C.) Hence the barometer and the boiling point of water may be employed for calculating the heights of mountains.

96. As water boils more easily under diminished pressure, so *it boils with more difficulty when the pressure is increased.* An increase of pressure can be produced, not only by the air, but by the steam of the water itself, if new steam be constantly generated, while the escape of that already formed is prevented. This is best done by heating water confined in a strong and firmly closed vessel. For this purpose, a Papin's Digester may be used, in which water may be heated to the temperature of 392° F. (200° C.), and, indeed, still higher, whilst in open vessels it cannot be heated above 212° F. (100° C.) If the amount of steam in it is twice as much as in an uncovered vessel, the pressure is said to amount to two atmospheres; if there is 3, 4, 5, 10, 20 times the quantity, there is said to be a pressure of 3, 4, 5, 10, 20 atmospheres. Vessels of this kind are often employed to effect a complete penetration of the water into solid and hard substances. Thus, for example, water at 212° F. (100° C.) dissolves the gelatinous matter only on the surface of the bones, whilst water at a temperature ranging from 230° F. (110° C.) to 248° F. (120°C.) entirely penetrates the bones, and extracts the gelatine also from the interior of them.

97. *Air and Heat.—Heat expands the air* in exactly the same way as it does solid and liquid bodies, but to a much greater extent.

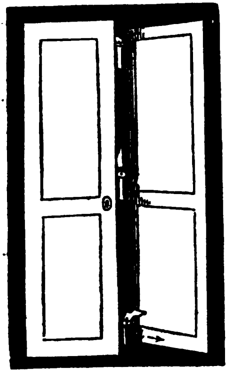
Experiment.—Dip a glass tube, provided with a bulb, into water, and heat the bulb gently; a part of the air is expelled, and escapes in bubbles through the water; consequently, there is not room enough in the bulb for the heated air; but it requires a larger space than it did in its cold condition. It follows from this, also, that the warm air is lighter than cold. If the lamp be removed, the air remaining in the bulb will contract on cooling, and water will be pressed up into the bulb, replacing the air which has been expelled.

Fig. 52.



98. *Current of Air.*—A great many phenomena of daily occurrence may be explained by the difference in lightness between warm and cold air. When a fire is lighted in a stove for the heating of an apartment, the air immediately in contact with the stove is first heated, becomes lighter, and ascends; colder air rushes in to supply its place, and this becomes likewise heated and ascends; consequently, a constant circulation of air is kept up. By a similar circulation, the whole atmosphere of the earth is kept in continual motion. At the equator the strongly heated air ascends and moves in the upper regions of the atmosphere towards the poles, while in the lower regions the current of cold air flows from the arctic zone towards the equator, in order here to restore again the equilibrium, disturbed every moment by the ascent of the warm air. These regular currents of air, the direction of which is somewhat diverted by the revolution of the earth on its axis, are called trade-winds.

Fig. 53.



In every heated apartment, a difference between the heat of the air near the ceiling and that near the floor is very perceptible. If a door or window in such a room be opened, a current of air is produced, the direction of which may easily be perceived by holding a lighted candle in the opening; the flame, when held above, at *c* (Fig. 53), is blown *from* the room; when placed below, at *a*, it is blown *into* it; consequently, the light warm air above rushes out of the room, and is replaced by heavier and colder air from below. A draught of air is also noticed in passing from the sunshine into the shade; where the sun shines, the warmer air ascends, and the colder air from the shade supplies its place. For the same reason, a current of air is produced wherever a fire is burning, in every stove, and round every lamp.

The air-balloons, first constructed by Montgolfier, strikingly show how buoyant air may be rendered by heat; these are caused to ascend merely by filling them with air, kept continually hot by a fire beneath.

99. *Gases.*—Formerly, atmospheric air only was known, but chemistry has shown that there are various kinds of air, light and heavy, poisonous and innocent; some of which are combustible, others not so, but which will support combustion, and others which extinguish it. It has also been shown that some sorts of air are concealed or chemically bound in many solid and liquid bodies, in which, from their external appearance, the presence of gases would never have been suspected; as, for instance, oxygen in oxide of mercury, and oxygen and hydrogen in water. These kinds of air are commonly called *gases*. The aeriform state is their natural condition, and they only assume the solid or liquid state on compulsion. Their densities, like solids and liquids (§ 23), are likewise expressed in numbers; but it must be remembered that in this case *atmospheric air*, and not water, is assumed as *unity*.

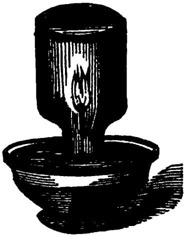
Vapour.—Many other bodies become aeriform on being heated, some quite easily, as alcohol and water; others with more difficulty, as sulphur and mercury; but, on being cooled, they lose their gaseous form, and assume again the liquid or solid state. Such species of air are called *vapour* or *steam*; they become gaseous only upon compulsion; their natural state is liquid or solid.

Composition of Air.

100. The last question concerning air is, What are its component parts? for that it is not a simple substance, not an element, has already been stated.

Experiment.—Fasten a piece of sponge to a wire, drop some alcohol upon it, and hold the wire in a vessel containing water, so that the sponge may be some inches above the water. Then kindle the spirit, and immediately place an empty bottle over it, so that the mouth of it may dip into the water; the flame will soon cease burning, and some of the water will rise into the bottle, in proportion to the amount of air disappearing during the combustion. The consumed air was oxygen, which united with the constituents of the alcohol. Close the bottle tightly with the finger, shake it briskly, and again open it below the water, when a little more water will enter. The air which is in the flask is called *nitrogen;* it is sometimes called *azote* (*a* privative, and *ζωή*, *life*), from its inability to support respiration. It forms the chief element of atmospheric air; this consisting of four measures of nitrogen, and only one of *oxygen.*

Fig. 54.



NITROGEN OR AZOTE (N).

At. Wt. = 14. — Sp. Gr. = 0.97.

101. *Nitrogen gas*, the preparation of which has just been given, is erroneously called *azote*, as we are continually breathing it without perceiving any injurious effects from it; it stops respiration only when it contains no oxygen, and because it contains none. The human body is so constructed, that it will not thrive on substances intended as nourishment if they are presented to it in their purest form. Strong alcohol acts as a poison, but when diluted with four or five times its quantity of water, as in wine, it is invigorating. Even the respiration of oxygen would soon destroy life, were it not diluted with four times its volume of nitrogen, as in atmospheric air.

Nitrogen has neither colour, smell, nor taste, and in a chemical point of view it must be regarded as a very inert or indifferent body, since it does not combine directly with any other substance. If we would combine it with another body, we must adopt a circuitous method. It is very widely diffused in nature, particularly in the organic kingdom, for we find it in all plants and animals. It is also contained in saltpetre or nitre, whence its name *nitrogen* (generator of nitre); its symbol is N.

102. Besides oxygen and nitrogen, air contains *vapour of water* and *carbonic acid.* The presence of the former is rendered obvious by the fall of rain, snow, dew, &c.; and that of carbonic acid can easily be shown by letting lime-water remain exposed to the air, as in § 46, or by shaking it in a flask containing air. Lime has an affinity for carbonic acid, and forms with it an insoluble salt (carbonate of lime, or chalk). This occasions a cloudiness in the liquid; it is the affirmative answer to the question put by the lime-water to the air. If you ask, What is the source of this carbonic acid? the reply is, It is formed wherever substances are burning, wherever men and animals are breathing, and wherever decay and putrefaction are taking place.

In 100 measures of atmospheric air are contained—

79	measures of	nitrogen,	or N.
21	"	oxygen,	" O.
$\frac{1}{30}$—$\frac{1}{15}$	"	carbonic acid,	" $C\,O_2$.
and variable quantities of water,			" $H\,O$.

In crowded rooms, and other confined places, the air becomes deteriorated; that is, poorer in oxygen and richer in carbonic acid.

That the air also contains other foreign ingredients is not strange, since it is the constant receptacle of volatile substances and dust. The air coming from the Spice Islands, even at the distance of eight or ten miles, is impregnated with the odour of cinnamon and cloves. The dust contained in the air can be discerned in the sunbeam, &c. These admixtures are usually so small, that they can neither be determined by weight nor by measure.

CHARCOAL AND FIRE.

CARBON OR CHARCOAL (C).

At. Wt. = 6.

103. If a piece of wood be placed on the hot hearth of a stove, it becomes brown, and finally black,—it is *charred or carbonised.* If water be poured upon a burning chip, the latter is extinguished,—it is seen to be also *carbonised.* A piece of linen, when inflamed and immediately smothered, becomes tinder. Tinder is *carbonised* linen. In the first case, the heat was not sufficiently strong entirely to burn the

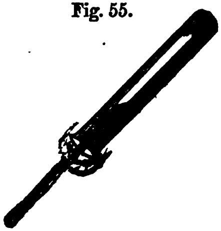
wood; in the second, the complete combustion was prevented by cooling; and in the third, by the exclusion of air. *All animal and vegetable substances, if only partially burnt, are converted into charcoal.* As charcoal, on exclusion of the air, cannot be melted, even in the strongest heat, so its external appearance is very different, according to the nature and structure of the substance from which it was prepared; indeed, this difference often extends to the innate properties of charcoal, as in wood-charcoal, soot, coke, bone-black, &c. In the charring of organic bodies, the charcoal is not generated, but it previously existed in them, though in chemical combination with other substances, which are principally driven off by heat, as is obviously the case from the fact that the carbonised body weighs much less than the original substances. All animals and plants consist, therefore, partly of charcoal; or, in chemical language, of carbon = C.

Carbon also exists in the mineral kingdom. It forms the principal element of common coal, brown coal, &c., which have all been formed from the vegetation of an earlier period. It is found almost pure in the diamond and in graphite, and, combined with oxygen, is contained in limestone, marble, chalk, and various other minerals.

104. Charcoal (C containing a small quantity of ashes).

Experiment.—Gradually introduce a burning splinter of wood into a test-tube. The part outside of the tube only will burn with a flame, while that within merely carbonises, because the air is excluded. On the same principle, wood-charcoal is prepared on a large scale. Piles of wood (charcoal kilns) are erected, which are covered with turf and moist earth, and the wood is then kindled. This would be extinguished, however, for want of air, if holes were not made, by wooden pokers, at different parts of the kiln, through which fresh air may be admitted, and the burnt air may escape. Only so much air should be admitted as is necessary for carbonising or half-burning the wood. When this has been accomplished in the neighbourhood of the holes, they must be closed, and new ones made at other points. At last all the openings are carefully stopped, that the

Fig. 55.



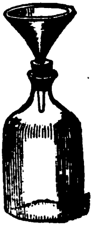
fire may be suffocated. When cold, the wood will be found black throughout and carbonised, the shape of the knots and annual rings being still perceptible. One pound of wood yields about one quarter of a pound of charcoal.

105. *Experiments with Wood-charcoal.*

Experiment a.—Weigh a piece of freshly-burnt charcoal, and let it remain for a day in a moist place; it will now weigh more than before, owing to its having *imbibed air and moisture.* If the charcoal be now put into hot water, the air will escape from it in numerous bubbles, being expelled by the heavier water, which replaces the air in the small interstices or pores of the charcoal. The snapping of this charcoal when placed upon the fire is hereby easily explained; the gases and watery vapour contained in the charcoal are expanded to such an extent by the sudden heat, that the charcoal is forced asunder, with a sort of explosion. Polished steel articles are often packed up in charcoal dust, that the air in the interior of the package may be kept dry, thus protecting the steel from rusting. Pulverised charcoal, on account of its absorbing power, may also be used for purifying sick rooms, and other apartments filled with deleterious vapours and gases.

Experiment b.—Grind freshly-burnt charcoal to a coarse powder, and place it on a filter. Then pour over it some red wine, or some water coloured black by a few drops of ink; the liquid will pass through the filter nearly or quite colourless, the charcoal having *absorbed* or retained the *colouring matter.* Sugar-refiners take advantage of this property of charcoal in bleaching their brown syrups.

Fig. 56.

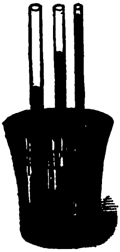


Experiment c.—Foul stagnant water *is deprived of its bad taste,* and is rendered clear and colourless, by being filtered through charcoal. In some large cities, where there is a scarcity of potable water, it is not unusual to filter through charcoal. Grain, likewise, which has become musty, may be rendered sweet by intimately mixing with it pulverised charcoal, and allowing them to remain some weeks in contact. Charcoal will also retard decay in vegetable and animal substances for a long period, and water remains pure for years in vessels which have been charred upon the inside; potatoes may be kept in cellars longer without sprouting or rotting, when laid in with charcoal dust; and meat, when packed in it, passes more slowly into a state of putrefaction.

Experiment d.—Charcoal renders ordinary brandy pleasanter in taste and smell, by absorbing into its pores an acrid volatile oil, *fusel oil*, with which some crude brandy is contaminated. It also deprives beer of its bitterness, by absorbing certain *component parts of the hops.*

106. The cause of this remarkable power of charcoal to attract and retain within itself such various substances, depends on its spongy, porous character. If a plate of glass be dipped into water and immediately removed, some of the water will remain adhering to its surface, showing that the water and glass have an attraction for each other. This power is called surface-attraction, or *adhesion.* This adhesion can be better illustrated by dipping a glass tube with a fine bore into water; the water rises in it, and the rise in the tube will increase in proportion to the decrease of the diameter. Such tubes present a great surface of glass to a small amount of liquid, and the sides are in such close proximity, that they aid each other in drawing up the water into the tube. This kind of adhesion is called *capillary attraction.* It is this which causes oil to rise in the lamp-wick, the spreading of water in blotting-paper, and its diffusion through sugar, brick walls, &c. In the same manner, *all solid bodies which have many pores and consequently much surface, attract fluids and gases.* A piece of charcoal, the size of a walnut, is intersected by many hundreds of partitions, which, if they could be placed by the side of each other, would cover a space a thousand times larger than the piece of charcoal itself covered. The force of attraction of this large surface is so powerful, that the charcoal can absorb from 80 to 90 times more than its own bulk of many kinds of gas. It is very probable that these gases, by such a compressure into 80 or 90 times smaller space within the charcoal, become fluid or solid.

Fig. 57.



In the case of spongy platinum (§ 85, *c*), a yet more porous substance than charcoal, heat is produced, in consequence of the absorption of oxygen and hydrogen rendering the platinum red-hot. Heat, also, but to a less extent, is developed in charcoal when it absorbs gases; the charcoal may even become heated to redness, undergoing spontaneous combustion, by heaping together large masses of it in a pulverised state, and many an unfortunate accident has occurred from this cause, especially in factories for the manufacture of gunpowder.

Hydrogen and oxygen, however long they remain in contact, do not enter into chemical union, but when the mixture is brought into contact with spongy platinum they instantly unite, forming water. This will be easily understood, when it is remembered that chemical force acts only at insensible distances, and consequently only when substances are in the very closest contact. In spongy platinum, as in other porous bodies, gases can be condensed to the 80th, and indeed, in the former case, to the 800th part of their volume; they must therefore touch each other from 80 to 800 times more closely than in their natural condition.

107. In addition to wood-charcoal, the following *other kinds of charcoal* have many different applications.

Soot, or *lamp-black* (C containing empyreumatic matter), is charcoal in a state of minute division, which is deposited from carbonaceous gases, commonly from illuminating gas; for instance, from the flame of common coal, wood, oil, rosin, &c., when during the combustion there is an insufficient supply of air. One variety of superior quality is called lamp-black. (§ 116.) The soot must be freed from the empyreumatic substances, either by igniting it thoroughly in a well-closed vessel, or by treating it with strong alcohol. Soot, as is well known, is our most important black colouring substance (Indian ink, printing-ink).

Coke, or carbonised coal (C generally containing considerable quantities of ashes), has a grey colour, is more or less porous, is very hard, and has a metallic lustre; it burns without forming soot, and gives out an intense heat; hence it is an excellent fuel, and especially adapted for the smelting of iron, and for the heating of locomotive boilers. Coke is obtained as a secondary product in the preparation of illuminating gas from coal. (§ 118.)

Bone-black (C intimately mixed with bone-ashes, and generally also with some azotised substances) is obtained by heating bones in close vessels. The carbon contained in it amounts only to about one-tenth part of the whole, the other nine-tenths being bone-ashes; but notwithstanding this, its decolorising power is so strong, that it is preferred to all other kinds of charcoal as a means of abstracting colour from the syrup of brown sugar, or from other dark liquids.

Two sorts of carbon found in the mineral kingdom, viz., graphite and the diamond, possess very remarkable, yet different, properties.

Graphite, or plumbago (crystallised *black* carbon), a grey substance, having a metallic lustre, imparts its colour so readily to other bodies, that it is used for making lead pencils, and for giving a black polish to iron articles, such as stoves, &c.; it is so soft and lubricating, that it is added to grease for the purpose of preventing friction in wheels and machinery; it is also so nearly incombustible, that crucibles are made of it, which stand the strongest heat without burning (blue-pots).

Diamond (crystallised *colourless* carbon) is the hardest of all bodies. In external appearance it has not, indeed, the slightest resemblance to charcoal, yet it can be entirely burnt up in oxygen, and carbonic acid is the only product obtained from it, and exactly so much is obtained as would have resulted from the combustion of an equally heavy piece of wood-charcoal or coke. In order to crystallise a substance, it must first be rendered fluid, which is done either by melting or dissolving it. Charcoal can neither be melted by the strongest heat, nor dissolved in any known liquid. Should a method ever be discovered for rendering it liquid, then diamonds could certainly be artificially imitated.

108. Carbon shows very clearly how one and the same body can have quite different forms and different properties. In wood-charcoal, soot, coke, and animal charcoal, it is black without any determinate shape (*amorphous*), and very combustible; in graphite it is black, with a crystallised foliated structure, and is nearly incombustible; in the diamond it is colourless, and is crystallised as a four-sided double pyramid (octahedron), and is likewise almost incombustible. Hence carbon is said to be *dimorphous*, having two different crystalline forms. If a body can assume more than two crystalline forms it is said to be *polymorphous*, having many forms.

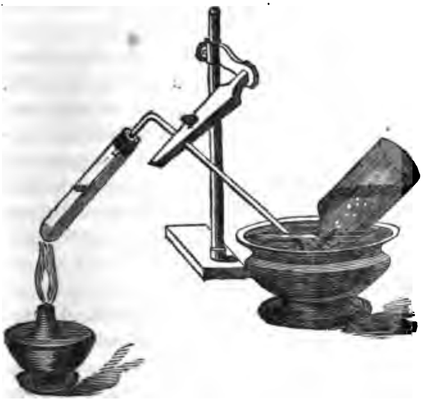
This property, which many elements have, of assuming different forms, is also called *allotropic* (from ἀλλοτρόπος, *different* *nature*), and it is designated by annexing Greek letters to the chemical symbols. Accordingly, carbon occurs in the three following allotropic states or modifications; as C α in the diamond, C β in graphite, and C γ in wood-charcoal.

The cause of this difference depends upon the relative position of the particles or atoms constituting the body towards each other. The same fibres of cotton, which, after carding, are parallel to each other, when matted together without order, constitute paper or pasteboard; when loosely woven together, wadding; when twisted, yarn or thread; and when they are made to intersect each other regularly, or in some intricate manner, cloth, stockings, velvet, &c. Nature also impresses different forms upon the same substance, but in a still more varied and artistical manner. The adaptation of the atoms to each other is not rendered visible to us, even by the aid of the strongest microscope; but this theory may be regarded as correct, since it explains the subject in a simple and natural manner.

109. *Charcoal and Oxygen.*—Charcoal undergoes no change on exposure to the air, or when imbedded in the ground. It is not decomposed at common temperatures, that is, it does not enter into combination with the oxygen of the air or of water. But this, as is well known, takes place very readily, when heated to redness. It then burns and disappears, with the exception of a small quantity of ashes. The heat thus developed is the result of its chemical combination with the oxygen of the air. The gas generated is called *carbonic acid*, which forms, with lime-water, a white precipitate (carbonate of lime), as has been stated previously. Carbonic acid consists of one atom of carbon and two atoms of oxygen, consequently its formula is $= C\,O_2$. It may also be obtained as follows.

Carbonic Acid.—Experiment.—Mix 109 grains of oxide of mercury with four grains of charcoal, and heat them in a test-tube. (§ 56.) A lighted taper introduced into the gas is extinguished, a sign that it contains no free oxygen. If you shake it with lime-water, the liquid becomes turbid, and on shaking the flask the finger is sucked in, or rather it is pressed into the neck of the flask by the atmospheric air—a proof that the gas was absorbed by the lime-water, and that a vacuum was produced within the vessel. If the oxide of mercury had been heated by itself (§ 56), it would have separated into mercury and oxygen; and this also happens in the present experiment, but the oxygen does not escape as such, it having previously united with part of the charcoal; the gas evolved is *carbonic acid.* The mercury is found, as a metallic mirror, at the upper part of the test-tube. After the experiment is finished, some charcoal still remains in the test-tube, for only 3 grains of it have united with the 8 grains of oxygen contained in the oxide of mercury; consequently, in the same proportions as in the burning of charcoal in pure oxygen. (§§ 63, 70.) We see that 3 grains of carbon combine with as much oxygen as 101 grains of mercury, or (§ 70) with as much oxygen as 8 grains of sulphur, 6 grains of phosphorus, 23 grains of sodium, or 20 grains of iron. These numbers are called *equivalents;* they indicate that 3 grains of carbon have the same chemical value as 101 grains of mercury, or as 8 grains of sulphur, &c. In the same sense, when we see a steam-engine perform, in one day, the work for which four horses or twenty-four men were required, we say that the power of the steam-engine is equivalent to the power of four horses or twenty-four men. (§ 164.)

Fig. 58.



110. *Carbonic Oxide Gas.*—When charcoal, during combustion, has a sufficient supply of air, then carbonic acid, or CO_2, is formed; but if there is a deficiency of air, then 3 grains of charcoal unite with only half as much oxygen, namely, with 4 instead of 8 grains, and there is produced but half-made carbonic acid, as it were, which is called carbonic oxide gas $= CO$. Carbonic oxide gas is extremely poisonous when inhaled, and constitutes what the miners call coal-gas. This gas is always formed when charcoal burns slowly, for example, in a chafing-dish, because the ashes, accumulating round the pieces of

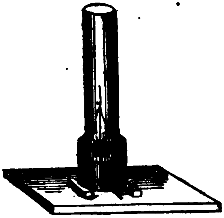
charcoal, obstruct the access of air; and it is also formed when the damper of a stove is closed, before the coal is burnt out, since in this case the draught of air, and consequently the supply of sufficient oxygen, is prevented. Notwithstanding repeated warnings, accidents not seldom occur from the fumes of burning charcoal. Carbonic oxide burns when kindled, with a blue flame; it takes up the deficiency of oxygen not supplied to it by the air while forming, and is converted into carbonic acid; that is, it takes up as much again oxygen, and $C\,O$ becomes $C\,O_2$. The blue flame which is always perceived on feeding the fire with fresh coals, or in large masses of glowing coals, is burning carbonic oxide gas.

COMBUSTION.

111. Every combustion with which we are familiarly acquainted is caused by a rapid chemical union of combustible bodies with the oxygen of the air, and the process may be regarded as one of oxidation. The consumed or oxidised combustible substances, that is, the compound of the fuel with oxygen, are mostly aeriform. We call them smoke, which will not support combustion. It follows from this, that, in order to maintain combustion, *fresh air must be continually supplied* to the fire, and the *smoke conducted off*. This is effected by a current of air.

Experiment.—Place the glass cylinder of a lamp over a lighted candle, which will soon be extinguished, because no fresh air can enter from below. The candle is also extinguished when the cylinder is covered at the top, although the cylinder is so held that the air can gain admittance from below; it is extinguished in this case, because the escape of the burnt gases is prevented. If the cylinder is placed uncovered on two pieces of wood, the candle continues to burn quietly, and by holding a taper recently extinguished near the lower opening, it will be obvious, from the direction of the smoke, that air rushes in at the bottom, but escapes at the top, having become hot and lighter during the process of combustion.

Fig. 59.

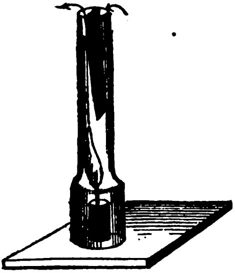


The hand can be held tolerably close over the flame of a lamp without being burnt, but if the flame be surrounded by the glass cylinder, the heat cannot be borne, unless the hand be much further removed from the flame. In the former case the hot air radiates in all directions, while in the latter it is confined by the cylinder; consequently the hot air must issue from the top *more rapidly*, and the cold air enter *more rapidly* from below to replace it. Owing to this increased current of air, cylinders effect a brisker and more perfect combustion, and cause a brighter and stronger illuminating flame.

Chimneys are to fireplaces what cylinders are to lamps. It is well known that narrow chimneys draw better than wide ones; the air escapes from the former hotter and more rapidly; hence a greater quantity of cold air is supplied to the fire, causing it to burn more freely.

Experiment.—If the upper part of the cylinder of a lamp be divided into two channels by a partition down the middle, the candle will then burn, even if access of air be cut off from below. The smoke of a glimmering taper will be drawn inwards on one side and expelled from the other, as indicated by the arrows in the figure; a draught of air sets in from the top to the bottom, which supplies the oxygen requisite for combustion; that this current of air exists is also made evident by the quivering motion of the flame.

Fig. 60.



112. In common lamps and candles, air has access only to the outside of the flame; hence combustion goes on only at the circumference, and not simultaneously in the interior, as is indicated by the dark central portion. But if air be admitted into the interior of the flame, this dark portion disappears; then more perfect combustion is effected, with the production of increased light. On this principle the so-called *Argand* lamps are constructed, to which are adapted circular wicks, so that the air has access, not only to the outer surface of the flame, but is admitted from below directly through the centre of the flame, causing it to burn in the form of a hollow ring. They are also called lamps with a double

Fig. 61.

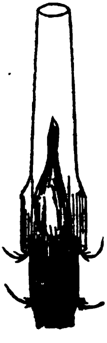
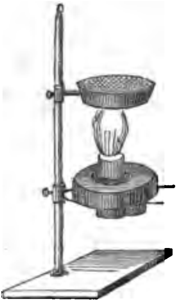


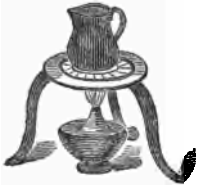
Fig. 62.



draught. The so-called ***Berzelius Spirit-Lamp***, universally employed in chemical laboratories, when a higher heat is required than a common spirit-lamp can yield, is constructed on this principle. It is made of sheet brass, is attached to a brass stand, and is provided with several rings of various sizes for holding porcelain dishes, crucibles, and other vessels, that are to be heated. In using this lamp, care must be taken that sufficient space be left between the vessels and the chimney for the escape of the hot air, and for the diffusion of the upper part of the flame. If this be not done, the combustion will be imperfect, and consequently less heat be given out. When it is desired to feed the lamp with more alcohol, the flame must first be extinguished, as otherwise the alcohol might take fire and cause serious inconvenience.

113. In order to kindle a substance, and to keep it continually burning, it must first be *heated to a certain point, and then maintained at this temperature.*

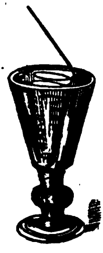
Fig. 63.



Experiment.—Heat in a small vessel some ashes or sand, on which a few phosphorus lucifer-matches have been placed; the latter, or more correctly the phosphorus on them, will not inflame until the ashes are heated to from 150° F. (65° C.) to 158° F. (70° C.), which can be readily ascertained by the thermometer.

114.—*Slow and Rapid Combustion.*—*Experiment.*—If a coil of fine platinum wire, being raised to a white heat in the flame of a spirit-lamp, be plunged quickly into a heated goblet into which a teaspoonful of strong alcohol has been poured, it will continue to glow in the vapour of the alcohol, whilst it would soon have ceased glowing in the air. The alcohol undergoes a *slow* combustion, that is, it unites with a small quantity of oxygen, and the heat thus liberated is sufficient to keep the wire *red-hot*. A disagreeable sour smell will also be perceived, proceeding from the new combination formed between the alcohol and oxygen during the slow combustion, and which may be regarded as partially burnt alcohol. When alcohol is

Fig. 64.



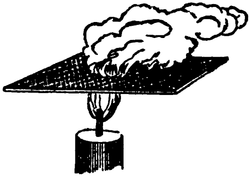
kindled, it burns briskly and completely, and the products emit no smell; therefore the combinations formed during the rapid or complete combustion must be different from those formed during the slow or incomplete combustion. Something similar to this is perceived with all other combustible bodies. The unpleasant odour caused by the singeing of the hair, the scorching of wool, the boiling over of milk, and the smouldering of blotting-paper, is the consequence of incomplete combustion; when the combustion is perfect, no bad smell is perceptible.

If in the last experiment ether be substituted for the alcohol, and the wire be brought to a white heat, it will cause it to burst into flame; but the wire, if only red-hot, will not kindle it. The temperature of the red-hot wire is not sufficient to produce rapid combustion of the ether, but a stronger heat is required. As the phosphorus did not inflame until it was heated to 158° F. (70° C.), nor the ether until a higher temperature was attained, so all combustible substances require a certain degree of heat at which to enter into rapid combustion; some a higher and some a lower degree. When burning bodies are cooled below this temperature, they are extinguished. Red-hot iron will continue to burn in oxygen, but not in common air; heat enough is evolved during the combustion in oxygen to keep it burning, while, in the five times slower combustion in the air, sufficient heat is not evolved for the continuance of this process. Coal requires for sustained combustion a stronger heat than wood; therefore the pieces must lay close upon each other in the grate or stove, or they will cool too much, and cease burning; wood continues to burn, even when spread loosely about on the hearth of the stove. A glowing coal is extinguished much sooner when placed on iron than on wood, for the iron, a good conductor of heat, withdraws the heat more rapidly than wood, a bad conductor.

Even the flame of a candle, or of a spirit-lamp, can be cooled to such a degree by iron as to be extinguished.

Experiment.—If you introduce a piece of wire gauze, such as is used for sieves, into the flame of a lamp, this will be suppressed as though a piece of tin plate were held over it, and smoke, but no flame, passes through the net-work. This smoke, if kindled by a match, will again burn. The smoke in passing through the iron gauze has become cooled down below the temperature necessary for burning; if this temperature be restored by the application of a taper, or by the gauze having reached a white heat, the smoke is again kindled. An illustrious English chemist has made a successful application of this principle for the prevention of the explosions so often occurring in coal mines. In many mines a combustible gas (fire-damp, or light carburetted hydrogen) issues from the fissures of the coal, which, mixing with the atmospheric air, forms an explosive gas, which might be fatal to the miner who should carry a burning lamp into a vein filled with such a gas. But when the flame is enclosed within an iron net-work, the explosive gas only burns within the cage; the miner thus warned has time to withdraw, and this dangerous gas is afterwards expelled by appropriate means. (*Davy's Safety-Lamp.*)

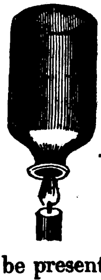
Fig. 65.



115. *Perfect Combustion.*—In the combustion of hydrogen, water is formed (§ 87), and in the combustion of carbon, carbonic acid. (§§ 63, 109.) Both of these products are also formed in the combustion of most other substances familiar to us, as these generally contain hydrogen and carbon, on which depends their capacity for burning.

Experiment.—Invert an empty bottle over a burning candle, so that it may receive the hot gases as they form; it becomes clouded on the inside, from the deposition of moisture which is condensed from the smoke upon the cold surface of the glass. This smoke consequently contains *watery vapour.* This explains why, on heating a vessel over a lamp, moisture is deposited on the outside as long as it remains cold. Pour lime-water into the flask, and agitate it. The liquid will become turbid, and deposit, on standing, a white powder (carbonate of lime); thus the smoke contains also *carbonic acid;* some *nitrogen* also must of course be present, as it existed in the atmospheric air which was used in maintaining the fire.

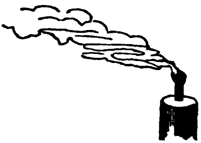
Fig. 66.



These component parts exist likewise in the smoke which issues from the chimneys of houses, whether formed from the combustion of wood, common coal, or brown coal; and are contained in the invisible current which ascends from an alcohol or oil flame.

116. *Imperfect Combustion.—Experiment.*—If you extinguish a lighted candle having a long snuff, you can rekindle the smoke ascending from the wick, even at some distance; this smoke consists of the combustible gases into which the tallow has been converted by the heat. It is half-burnt tallow, and has an unpleasant smell. On being extinguished, sufficient heat is not retained for its complete combustion, but this commences again when the smoke is heated and kindled by a match. Completely burnt tallow, that is, tallow converted into carbonic acid and water, has no smell.

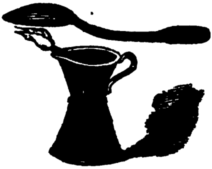
Fig. 67.



Experiment.—If you stop up the draught of a burning astral or Argand lamp (§ 112) with a piece of paper, the flame will immediately become dark and red, emitting a thick black smoke, which has a very disagreeable odour, and which covers a piece of paper held over it with soot. There is *imperfect combustion of the oil, owing to the exclusion of the air;* a part of the carbon contained in the oil remains unburnt, and escapes as *soot.*

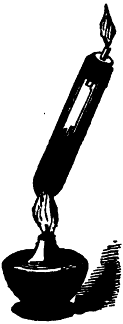
Experiment.—Refrigeration gives rise to the same phenomenon, as, for example, when an iron spoon is held over the flame of a common oil-lamp, so as partly to suppress it. The iron, being a good conductor, not only cools the flame, but it also obstructs the draught of air; a part of the carbon, therefore, remains unburnt, and is deposited as soot upon the spoon. In this way watchmakers prepare *lamp-black* for marking their dial-plates. A tallow candle yields an invisible and scentless smoke when allowed to burn quietly, but, on the contrary, a sooty and disagreeably smelling smoke when the flame is cooled by blowing upon it, or moving the candle about. In order to smoke meat rapidly, green or wet wood is burnt; this yields a thick, black smoke, because it cannot be heated above 212° F. (100° C.) as long as it contains water, and at this low temperature it is only imperfectly burnt.

Fig. 68.



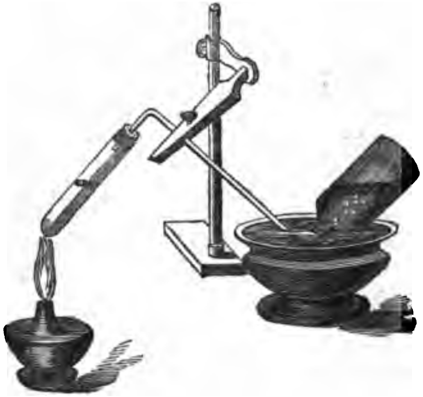
117.—*Illuminating Gas and Flame.—Experiment.*—To acquire a clearer understanding of the products of *imperfect* combustion, put into a large test-tube some wood-shavings, and heat it, having previously adapted to the opening a cork, provided with a glass-tube or a piece of tobacco-pipe. (Fig. 69.) The gaseous matter which is formed will pass through the tube, and, on being kindled, will burn with a luminous flame. Previously to being kindled, the shavings emit a sour and empyreumatic odour; this smell, however, vanishes entirely on burning. *Flame, then, is caused by burning gas.* Substances which do not become gaseous on combustion can only glow, but cannot burn with a flame. Some charcoal will remain unburnt in the test-tube, owing to a deficiency in the supply of air. An application of this principle is made on a large scale in the preparation of *illuminating gas* by heating of common coal, rosin, &c., in closed iron vessels. Every candle, every oil-lamp, is an apparatus for the preparation of gas on a small scale.

Fig. 69.



118. *Experiment.*—Repeat the experiment with pulverised coal, but conduct the gas, through a bent glass tube, into a jar placed over the pneumatic trough, and collect it as already described. The gas is colourless, and on being ignited burns like hydrogen, but with a far more luminous flame. Its chief constituent is also hydrogen, chemically united, however, with some carbon (*carburetted hydrogen gas*). During combustion, both constituents of illuminating gas unite with the oxygen of the air, and are converted into carbonic acid and water.

Fig. 70.

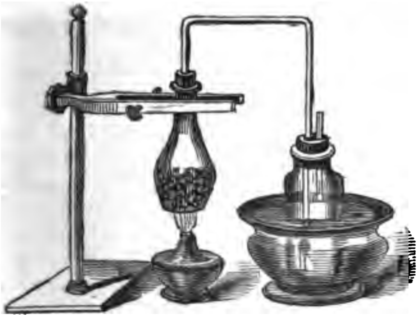


Coke, already alluded to, which is tolerably pure carbon, remains behind in the tube.

Carbon forms with *hydrogen* a very numerous class of chemical compounds; those with which we are best acquainted are, — *a*) *light carburetted hydrogen* ($H_2 C$), which issues from the fissures of many coal-beds (fire-damp, § 114), and is likewise always generated wherever vegetable matter is putrefying under water (marsh gas, § 446); owing to its larger proportion of hydrogen, it is lighter, and, on account of its smaller proportion of carbon, it burns with a paler flame, than *b*) *heavy carburetted hydrogen* ($H_4 C_4$), commonly called olefiant gas. (§ 503.) These two gases ($H_2 C$ and $H_4 C_4$) form the principal constituents of the common illuminating gas.

119. *Experiment.*—Heat some pieces of wood, and conduct the volatile matter through a tube into a bottle immersed in cold water, and adapt to the cork of the latter another open tube, for the escape of the *illuminating gas.* Two fluids will be condensed at the bottom of the flask; one a very thick viscid fluid, and the other a thinner watery substance. The first is called *wood-tar;* it is resinous—*i.e.*, it is insoluble in water. The other is called *wood-vinegar*, or pyroligneous acid; both its taste and action upon blue test-paper indicate that it is an acid. *Illuminating gas, wood-tar, and wood-vinegar did not previously exist in the wood,* but were formed during the imperfect combustion from its constituent parts, carbon, hydrogen, and oxygen. Such new-formed substances are called *products;* and in the present case, moreover, products of the incomplete combustion (dry distillation) of wood. Hydrogen predominates in illuminating gas; oxygen in pyroligneous acid; and carbon in wood-tar; all of them, owing to the deficient supply of air, were but partially burnt, and they

Fig. 71.

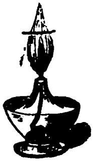


are hence capable of undergoing further combustion in the air, and, like the wood from which they originated, of being completely converted into carbonic acid and water. A portion of wood and coal is always imperfectly burnt in our fireplaces, and, therefore, soot is deposited in the funnels and chimneys; the tar and acid are also deposited, as a black shining substance, upon the jambs of the chimney.

The operation by which, as in the present case, liquid products may be obtained from a solid substance, is called *dry distillation*. Most of these liquids have a brown colour, and a peculiar, unpleasant, empyreumatic smell and taste.

120. It has been previously stated that hydrogen burns very easily, and with a flame, while carbon burns more difficultly, and without flame; thus is easily explained why fuel burns with a flame at the commencement of the combustion, but finally only glows; it is the hydrogen which *first* burns with a *flame*, and afterwards the carbon, with a mere glow, without flame. All combustible substances that contain hydrogen and carbon burn in a similar manner. Burning wood presents the most convincing illustration of this fact.

Fig. 72.



121. The flame of alcohol consists of two parts; the dark central part is alcohol vapour, and the bright envelope around this is alcohol vapour uniting chemically with the oxygen of the air. The tapering form of the flame is owing to the ascent of the hot gases, and the rushing in of cold air from below. The alcohol is drawn up from the lamp by the capillarity of the wick (§ 106); it burns with a light, but if a twisted wire or some other solid body be introduced into it, it will then burn vividly. If a thin wire is placed across the flame, it will be heated to redness near the margins of the flame, while in the interior it will remain dark; consequently, the external part is much hotter than the central part of the flame. The point of greatest heat is indicated by the mark in the figure, and vessels to be heated over the spirit-lamp should never be placed below this point. This may be rendered very evident by applying a lucifer-match to this part of the flame, when it will take fire at once; but not so quickly if thrust into the centre of the flame.

122. In the *flame of a candle or lamp*, three parts can be

Fig. 73.

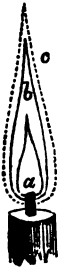


Fig. 74.

distinguished; in the *middle* (*a*, Fig. 73), the dark centre, consisting of illuminating gas (decomposed tallow); *around this* (*b*), the luminous cone, consisting of burning hydrogen, intimately mixed with carbon at a white heat; and *on the very outside* (*c*), a thin, scarcely perceptible veil, in which carbon is burning. If we imagine the flame to be cut horizontally through the centre, it would present nearly the same appearance as in Fig. 74. The middle circle is carburetted hydrogen, or illuminating gas; the hydrogen of which burns *first*, and the great heat thus evolved brings the carbon to a white heat (this is indicated by the second circle); and finally, in the exterior circle, the carbon is burnt. The heated carbon in the second ring imparts to the flame its illuminating power, just as the glowing wire rendered the alcohol flame luminous. If a cold knife be introduced into the flame, a portion of the carbon will be so much cooled that it cannot burn, and will be deposited upon the knife in the form of soot. If a wire be held through the flame, the glowing part at the hot margins will remain clear, while soot will be deposited upon that part of it which is in the interior of the flame.

The *brightness* of a flame always depends, as the foregoing experiments show, upon the presence of a solid body, usually soot, which glows in the flame; if it be only heated to redness, the flame will give out a smoky red light, but, on the contrary, a brilliant light when heated to a white heat.

The four simple substances now treated of form the chief constituents of plants and animals, and are hence called *Organogens* (generators of organic bodies).

RETROSPECT OF THE ORGANOGENS (OXYGEN, HYDROGEN, NITROGEN, AND CARBON).

1. As we distinguish on a small scale, within ourselves, body and spirit, so we distinguish also on a large scale, in nature, matter (body) and forces (spirit).

2. All matter is ponderable. Absolute weight determines

the actual weight of a body in the air; specific weight the relative weights of substances of equal bulks.

3. Bodies occur in three states of aggregation; they are either solid, liquid, or aeriform.

4. The earth may be regarded as the representative of solid bodies; water, of liquid; air, of aeriform bodies; and fire (light and heat), as the type of the natural forces.

5. The individual particles of bodies are held together by a force called *cohesion*. It is strongest in solid, and weakest in aeriform substances.

6. This force is weakened by heat, strengthened by cooling; bodies are expanded by heat, and the individual particles are removed from each other; by cooling, on the contrary, they are again contracted into a smaller space.

7. Heat also changes the state of aggregation of bodies; it renders solid bodies liquid (melting), and liquid bodies aeriform (evaporation, boiling).

8. On cooling, gaseous bodies become fluid (distillation, rain), fluids become solid (hardening, freezing).

9. On the melting and evaporation of solid and fluid bodies, heat becomes *combined* or latent (production of cold); on the freezing of fluid and the condensation of gaseous substances, heat becomes *free* (production of heat).

10. All bodies contain, accordingly, latent heat, and the fluids always less than the gaseous.

11. Solid bodies also become fluid by *solution* in a liquid. If they separate again from such solutions in a regular form, they are said to be *crystallised*. Mobility and time are necessary for crystallisation.

12. Gaseous bodies which on cooling easily become liquid, are called *vapours;* those which are converted into liquids with difficulty, or not at all, are called *gases*.

13. The cohesion of bodies can only be destroyed by cutting, breaking, &c.; hereby their form only is changed, their nature and constituents remaining the same. These are external or *mechanical changes*.

14. But changes also occur by which the properties and constituents of bodies are so completely altered, that they can no longer be recognised as the original bodies, but must be regarded as new bodies. These are internal or *chemical changes*.

15. A power, more or less inherent in all bodies, is regarded

as the cause of the chemical changes; it is called *affinity*, or *elective affinity*. In inanimate or inorganic bodies this power rules unrestrained, but in living or organic bodies it is regulated by the *vital power* of vegetables and animals.

16. Affinity acts only at insensible distances; when bodies are in the closest contact.

17. Affinity is stronger between bodies in proportion to their greater dissimilarity, and so much the weaker the more they are alike.

18. Chemical changes may be produced in two ways; either by the combination of simple bodies into compound ones (synthesis), or by the separation of the compound bodies into their constituent parts (analysis).

19. By analysis bodies are finally obtained which can be no further decomposed; these are called simple bodies or *chemical elements*. About sixty of them only are as yet known. One element cannot be converted into another.

20. Almost every chemical compound may be decomposed by electricity or galvanism.

21. By heat, the affinity of bodies for each other is sometimes strengthened, sometimes weakened; heat assists both in combining and in decomposing bodies.

22. All chemical combinations take place according to fixed *measure* and *weight*. This conformity to law also prevails where substances combine together in several proportions (degrees of oxidation, &c.).

23. *Heat* is evolved during almost all chemical changes, and not unfrequently gives rise to the phenomenon of fire (combustion).

24. What is ordinarily called *combustion* is a combination of carbon or hydrogen with the oxygen of the air,—an *oxidation*.

25. *To oxidise* signifies to combine a body with oxygen. The body combined with oxygen is (in the wider sense) called an oxide.

26. There are two entirely opposite kinds of oxides, *acid* and *basic*; the metalloids form with oxygen, by preference, *acids*; the metals, by preference, *bases* (oxides in the more strict sense).

27. Acids and bases have a very great affinity for each other; when they combine together, the acid properties of the former and the basic properties of the latter disappear (neutralisation). The newly formed body is called a *salt*.

28. The chemical elements are designated by the initial

letters of their Latin names (chemical symbols); with the latter chemical *formulas* are constructed, which represent concisely the constitution of the compound bodies.

SECOND GROUP OF METALLOIDS: PYROGENS.

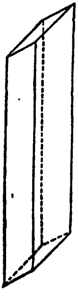
BRIMSTONE, SULPHUR (S).

At. Wt. = 16.—Sp. Gr. = 2.0.

123. SULPHUR, an article very familiarly known, which, on account of its easy combustibility, is employed in the manufacture of matches, &c., has neither taste nor smell. It has no *taste*, since it is not soluble in water. When we throw some flowers of sulphur into cold or hot water, it is not dissolved. We perceive taste only in such bodies as can be dissolved in water, since they alone will dissolve in the saliva; for example, there is a taste in salt and sugar, but none in insoluble substances, as stones, charcoal, starch, &c. Sulphur has no *smell*, as it does not volatilise at the ordinary temperature. We can only perceive smell in a body when volatile, consequently gaseous or vaporous particles are given off from it, and come in contact with the lining membrane of the nose.

124. *Experiment.*—Sulphur is *fusible.* Heat two ounces of flowers of sulphur in a small stone-ware crucible, over a spirit-lamp; it is converted, at a temperature a little above that of boiling water, into a thin, brownish fluid. If you pour some of it into cold water, you obtain again solid sulphur. If this, after being previously dried, is returned to the crucible, it will sink in the fluid mass, showing that solid is heavier than melted sulphur. Almost all other bodies behave in the same manner; ice, which floats on water, being an exception.

Fig. 75.

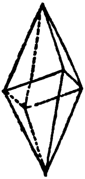


125. *Experiment.*—Sulphur may be crystallised. Let the crucible containing the melted sulphur stand till a crust has formed over the surface; break this quickly, and pour out the portion remaining fluid. Upon afterwards breaking the crucible, the cavity of the sulphur will be found lined with fine crystals, in the form of lengthened pillars (Fig. 75), which are called oblique rhombic prisms. This is the second method of forming crystals, and differs from the mode of obtaining those of saltpetre and salt (§§ 50, 52), inasmuch as in the one case the body was rendered liquid by solution, in the other by heat.

If the sulphur is allowed to cool quietly, without decanting the liquid portion, this also will become solid, and such a dense mass of crystals will be formed, that there will be no vacant space between them. This mass, on being broken, presents a glittering appearance, owing to the reflection of light from the surfaces of the minute crystals. Such a body is said to be *crystalline*, or to have a *crystalline structure.*

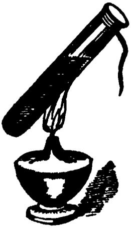
126. In different parts of the world, particularly in volcanic countries, large beds of sulphur (native sulphur) are not unfrequently found, and, in these beds, fissures and cavities studded with the most beautiful crystals, which required, perhaps, centuries for their formation. These native crystals have a very different form from those prepared by fusion. They appear like two pointed four-sided pyramids, applied base to base (Fig. 76); such a form is called an acute octahedron, because contained under eight acute triangles. Thus sulphur, like carbon in the diamond and graphite, assumes two different forms; it is *dimorphous.*

Fig. 76.



127. *Experiment.*—Sulphur may be made to assume a still different state. Heat a test-tube, supported by means of a wire twisted round it, and filled with powdered sulphur, over a spirit-lamp; on fusing, the sulphur runs together, so that it only half fills the tube. The sulphur first becomes thin, like water, but on further heating it becomes brown, and so thick and viscid that the tube may be inverted without the sulphur flowing out. Thrown into water while in this condition, it forms a transparent, soft, elastic mass, which, after a few days, is reconverted into solid sulphur. This sulphur, resembling melted glass, is said to be *amorphous*, a term applied to all other bodies having no regular form; such as gum, pitch, glue, &c.

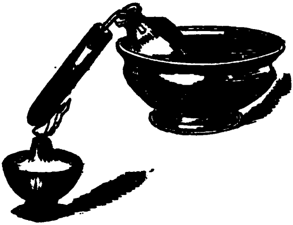
Fig. 77.



128. *Experiment.*—If the sulphur in the test-tube be heated still more strongly, at a temperature, perhaps, four times above that of boiling-water, it begins to boil, and is thereby converted into a reddish-brown vapour, *vapour of sulphur;* thus sulphur is *volatile*, and may, like water, assume all the three states of aggregation (solid, fluid, and aeriform). Solid sulphur is twice as

heavy as water, and its vapour six and a half times heavier than common air. Within the tube the vapour of the sulphur is transparent, and has a reddish-brown colour; but after escaping, on the contrary, it appears as a yellowish smoke, being condensed by the cold air into a dust of solid sulphur. If this vapour be conducted into a glass jar, immersed in cold water, the sulphur condenses in it in the form of a soft yellow powder, known in commerce by the name of *flowers of sulphur.* In the preparation of sulphur on an extensive scale, the operation is conducted in large chambers. The process by which a volatile substance is evaporated and condensed again into a solid is called *sublimation.* In distillation, the vapour is condensed into liquid (the distillate), in sublimation, into a solid (the sublimate).

Fig. 78.



If, in this experiment, the receiver were not kept cool, it would gradually become so hot that the sulphur would pass over as a fluid, and on this principle native sulphur is purified on a large scale. The earthy impurities, not being volatile, remain behind while the sulphur is distilled over, and again condensed. The melted sulphur is commonly poured into moistened wooden moulds, and is then called *roll-sulphur.*

129. *Experiment.*—Fill a test-tube half full of soap-boiler's lye; add to it as much flowers of sulphur as can be taken up on the point of a knife, and boil the mixture for some time; a part of the sulphur will be dissolved, imparting to the liquid a yellowish-brown colour. The clear liquid is now decanted, diluted with water, and vinegar added to it; it will immediately assume a milky appearance, owing to the separation of the sulphur in the form of an exceedingly fine powder, which is so light that a considerable time must elapse before it will subside. Collect the powder on a filter, wash it with water, and dry it at a gentle heat. It is called *milk of sulphur*, or *precipitated sulphur*, and is sulphur in its finest state of subdivision, caused by the separation of each of its particles by the water. Precipitated sulphur has a pale yellowish tint, but

on being melted it becomes distinctly yellow, owing to the union of the individual particles into a larger mass. This method is frequently employed in chemistry to convert solid substances into the finest powder. Such substances thus reduced to a fine powder are not unfrequently amorphous.

The solution of sulphur in lye is more complex than that of sugar or of salt in water; as several other peculiar combinations of sulphur with the component parts of water are formed at the same time. One of them, sulphuretted hydrogen ($H S$), is gaseous, and occasions the offensive smell which is emitted on the addition of vinegar to the solution of sulphur. The vinegar unites with the constituents of the lye, which then loses its power of holding the sulphur in solution.

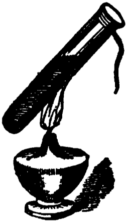
130. *Experiment.*—If sulphur be heated in a vessel with free access of air, as in an iron spoon, or be touched by some red-hot body, it *burns* with a blue flame; that is, it unites with the oxygen of the air, under the phenomenon of fire, and forms with the oxygen, as has been previously shown (§ 64), a suffocating gas, sulphurous acid ($S O_2$). If another atom of oxygen be added to this, there is then formed the common and very important acid, called sulphuric acid ($S O_3$).

This property which belongs to sulphur, of igniting and continuing to burn at a very moderate heat, is the reason of its being so commonly used for all *kindling purposes*. By means of it, other bodies more difficult of combustion may be heated to the temperature at which they can continue to burn (matches, gunpowder, fireworks, &c.). The kindling of a simple coal-fire well illustrates how, by gradual transition from easily inflammable materials to those of more difficult ignition, the latter are finally brought to that degree of heat at which they will ignite and continue to burn. Thus, sparks of iron, thrown out by the striking of the steel, ignite the finely divided charcoal of the tinder; this kindles the matches, by means of which, first straw, then wood, and finally coal itself, are brought to the temperature requisite for burning. The following is the scale in the order of combustibility:—tinder, sulphur, straw, wood, coal.

131. Sulphur is the *strongest chemical body*, next to oxygen, and has, like it, a powerful affinity for all other elements.

Experiment.—Boil some sulphur in a test-tube, and expose

Fig. 79.



a very thin copper-plate to the brownish vapour; the copper will glow vividly for some moments, lose its red colour and flexibility, become grey and brittle, and weigh one-fourth more than before. The newly-formed grey crystalline body is called *sulphuret of copper*. Both elements have intimately combined, and in fixed proportions. The properties of the sulphur as well as of the copper, have entirely disappeared. The great heat produced is a consequence of the chemical combination, since, in accordance with a law of nature, heat is evolved whenever bodies chemically combine with one another, but in most cases the heat does not amount to actual glowing or combustion.

In a similar manner almost all other metals may be converted into metallic sulphurets. We find many of these, however, already formed in the earth, and miners call them glance, blende, or pyrites. The pyrites having the lustre of brass, and found in almost all coal, is sulphuret of iron; red cinnabar is a sulphuret of mercury, &c. The sulphuret of copper, artificially prepared as above, occurs also as an ore, and is then called *copper pyrites*.

Experiment.—Mix three-fourths of an ounce of iron-filings, half an ounce of flowers of sulphur, and one-fourth of an ounce of water, in a small vessel, and put it in a warm place; the mass becomes heated, the water evaporates, and in half an hour a black powder will be obtained, in which no particles of iron or of sulphur will be perceived; a chemical compound, *sulphuret of iron*, is formed. If the two substances be mixed together without water, no combination will take place, unless they be heated to redness; the water effects the combination, by bringing the particles of the sulphur and iron into such close contact that they can attract each other. It is, as it were, the bridge by which one body passes over to the other.

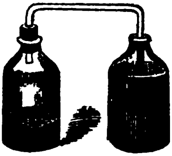
Sulphur has also another resemblance to oxygen—that of combining with other bodies in greater or less quantities, according to circumstances. The quantities here also are always fixed and unchangeable for every individual combination (law of definite proportions—stoichiometry). In the simple grey sulphuret of iron, 100 ounces of iron are always united with

57½ ounces of sulphur; in the yellow iron pyrites, 100 ounces of iron always unite with 115 ounces of sulphur (degrees of sulphuration); if more sulphur is present, it remains uncombined. The degrees of oxidation are distinguished by the terms *protoxides*, *sesquioxides*, and *peroxides*. In the combinations of sulphur, when the sulphur predominates, they are called *sesquisulphurets* and *persulphurets;* and when the sulphur is not in excess, they are called *protosulphurets;* and in the latter term, when there is a deficiency of sulphur, the syllable *sub* is substituted for *proto.*

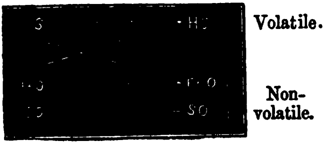
The chemical symbol for sulphur is = S. Protosulphuret of iron is expressed by the symbol Fe S; persulphuret of iron, by Fe S_2. Fe, the first two letters of the Latin word *ferrum*, is the symbol for iron.

SULPHURETTED HYDROGEN, OR HYDROSULPHURIC ACID (H S).

Fig. 80.

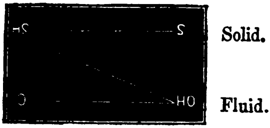


132. *Experiment.*—Put half an ounce of protosulphuret of iron (Fe S) and half an ounce of diluted sulphuric acid (§ 84) into a two-ounce flask, and quickly stop the flask with a cork, to which a bent glass tube is adapted. Introduce the longer limb of the tube into a bottle filled with cold water. The atmospheric air contained in the flask and tube first passes over, followed by a very offensive gas, which dissolves in the water, to which it likewise imparts its fetid odour of rotten eggs. This gas is called *sulphuretted hydrogen.* The decomposition in this case is similar to that effected in the preparation of hydrogen from iron. (§ 84.) Water is decomposed; its oxygen unites with the iron, forming protoxide of iron, and this unites with the sulphuric acid, forming green vitriol; but the hydrogen of the water escapes, and takes with it as a companion the sulphur contained in the sulphuret of iron. The light gaseous hydrogen possesses in a great degree the power of rendering other bodies aeriform on uniting with them, even those which are not volatile or have but a slight tendency to become so, just as an elo-

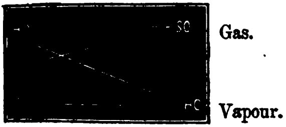


quent speaker can communicate his enthusiasm to a heavy and indifferent audience. Even carbon, which has never been liquefied, is converted into a light gas when combined with hydrogen, as in illuminating gas.

When the disengagement of the gas ceases, add some diluted sulphuric acid, that the gas may again be generated. The water is known to be saturated with the gas when, on shaking the bottle, the finger by which the opening is closed is no longer sucked in, or, more correctly speaking, pressed in. One measure of water contains two and a half measures of gas in a saturated solution. It is put up in small well-stoppered bottles, which are labelled *Hydrosulphuric Acid.* If the air be admitted, the solution becomes turbid, owing to the oxygen of the air uniting with the hydrogen of the sulphuretted hydrogen, forming water, and the consequent liberation of the sulphur as a fine powder.



If, during the evolution of the gas, the bottle of water be removed, the gas issuing from the tube can be ignited by a match; it burns with a blue flame, and its nauseous odour is no longer perceptible, but is replaced by the well-known odour of burning sulphur. Both constituents unite with the oxygen of the air, the sulphur forming sulphurous acid, and the hydrogen water.



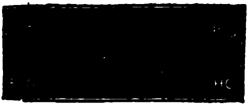
The inhalation of sulphuretted hydrogen is *detrimental* to health; hence precautions should be taken to avoid it. When experimenting with it, it is best to do so where there is a free circulation of air. A cloth moistened with a little alcohol, and held before the mouth, is likewise a good protection.

Sulphuretted hydrogen turns blue litmus-paper red; it also combines with many bases, and hence it is an acid. It has also been called *Hydrothionic Acid*, from two Greek words, signifying water and sulphur. Thus, oxygen is not essential to the acidity of a compound, since hydrogen also possesses this acidifying property; but the latter produces acids with but few elements, whilst oxygen does so with numerous elements.

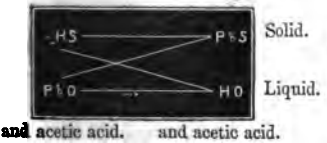
133. *Experiments with Sulphuretted-Hydrogen Water.*

Experiment a.—Drop some sulphuretted-hydrogen water upon a bright silver or copper coin, and upon a piece of lead and iron. The first three metals tarnish quickly, and finally become black; they combine with the sulphur, forming dark *metallic sulphurets*, whilst the hydrogen escapes; the iron, on the contrary, undergoes no change. Pb is the symbol for lead, plumbum.

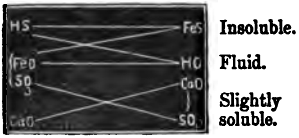
Experiment b.—Put into one test-tube a small portion of litharge, into another some ignited iron-rust, and pour upon them liquid hydrosulphuric acid. The yellow litharge, oxide of lead, becomes immediately black, an exchange of elements takes place, the hydrosulphuric acid gives its sulphur to the lead of the litharge, and receives in return the oxygen of the latter. Accordingly, *sulphuret of lead* and water are formed, and the offensive odour disappears. In the vessel containing the iron-rust, neither the colour nor the smell is changed—a proof that no chemical change has taken place.



Experiment c.—Repeat the same experiment with a small crystal of sugar of lead instead of the litharge, and some green vitriol instead of the iron-rust, together with a few drops of vinegar, these salts having been previously dissolved in a large quantity of water; the result will be the same as in the former experiment. Sugar of lead is the acetate of the oxide of lead; the salt of lead is converted into sulphuret of lead, which subsides sooner or later as a black precipitate. When this solution is extremely diluted it is only rendered brown. The acetic acid is set free, and remains in solution.



Experiment d.—If some lime-water or soda be added to the green-vitriol solution, which in the former experiment remained unaffected by the addition of sulphuretted hydrogen, it



will immediately assume a deep black colour. The added base effects, what otherwise would not have occurred, a combination of the sulphur with the iron, and for this reason, that the new base itself unites with the sulphuric acid of the green vitriol. Sulphuric acid has so great an affinity for the protoxide of iron, that it will not part with it unless in the presence of a stronger base, which the lime and soda have proved themselves to be. Lime is oxide of calcium, and is represented by the symbol Ca O.

From these experiments the following rules are derived:

a.) Sulphur, in its moist state, *i.e.*, when dissolved in liquids, has a very great affinity for metals, and converts metals, metallic oxides, and salts into metallic sulphurets.

b.) Most of the metallic sulphurets are *insoluble* in water; hence sulphuretted hydrogen is peculiarly adapted for precipitating metals from their solution, so that they can be separated and collected by filtration. If sulphuretted hydrogen be passed through a solution of acetate of copper, sulphuret of copper will be precipitated, and can be separated by filtration from the acid. All the sulphurets do not possess a black colour; sulphuret of antimony has an orange-red colour; sulphuret of arsenic a yellow, and sulphuret of zinc a white colour. On this is partly based the application of sulphuretted hydrogen as a test, that is, as a means of detecting many metals. Wine containing lead is blackened by hydrosulphuric acid.

c.) Many metals are precipitated from their solutions by the addition merely of sulphuretted hydrogen, as sulphurets; for example, copper, silver, gold, lead, mercury, tin, antimony, and arsenic (these are called *electro-negative*); and others are not precipitated until a stronger base is added; for example, iron, zinc, manganese, cobalt, and nickel (these are called *electro-positive*). Sulphuretted hydrogen may accordingly be used to separate one metal from another; it is, therefore, an important means of separation in analytical chemistry.

134. Hydrosulphuric acid has, as already mentioned, the formula H S, which indicates that it is composed of one atom of hydrogen and one of sulphur, and the similarity of this formula to that of water, H O, is apparent. Lead paper is used

for the detection of sulphuretted hydrogen, by which it is coloured brown or black. It is made by passing strips of paper through a weak solution of sugar of lead in water.

135. It is well known that during the decomposition of *animal substances*, blood, flesh, hair, urine, excrements, the white and yolk of eggs, &c., a putrid odour is evolved; this is owing to sulphuretted hydrogen, which is formed from the small quantity of sulphur contained in most animal substances, and from the hydrogen of the water, and is diffused in a gaseous form in the air. Hence it will no longer appear strange that copper vessels, if exposed to such an atmosphere, will tarnish, become brown, and, indeed, finally black.

136. Sulphur is also met with in *vegetable* substances, particularly in the leguminous plants—peas, beans, lentils, &c.—and in some acrid plants, such as mustard and horseradish. If these be heaped together in a pile when moist, they will, on decaying, likewise evolve sulphuretted hydrogen.

137. Finally, it remains to be stated that this gas occurs also in some *mineral waters*, as may be recognised by the smell and taste. Many of these springs—for instance, the celebrated springs of Aix-la-Chapelle—are resorted to by invalids, and are called *sulphur springs*. A rotten wooden water-pipe may convert an otherwise potable water, if it should contain sulphate of lime, into a nauseous sulphuretted water; but by clearing out the well, and laying down new pipes, the water may be rendered completely odourless and good.

SELENIUM (Se).

Selenium is an element which has great resemblance to sulphur. It is of rare occurrence, and is contained in the red matter deposited from certain varieties of sulphuric acid, especially after the acid has been diluted with water.

PHOSPHORUS (P).

At. Wt. = 32.—Sp. Gr. = 1.75.

138. Great care is required in experimenting with phosphorus, that it does not take fire at an unseasonable moment, as it continues burning with the greatest violence, and might occasion dangerous wounds. It may catch fire even when lying upon blotting-paper, particularly in summer-time, or by

the heat of the finger. Hence it must be kept, and also cut, under water. On being taken from the water, it should be held by a pair of forceps, or be stuck on the point of a knife. Prudence also would dictate to experiment with small quantities only at a time, and to have a vessel of water in readiness, in which it may be quenched in case it should catch fire.

139. Phosphorus is, in its properties, closely allied to sulphur, but it has an incomparably more irritable temperament. Sulphur may be regarded as the phlegmatic brother of phosphorus. Phosphorus, like sulphur, melts, boils, evaporates, and burns, but far more easily and rapidly. In winter it is brittle, in summer flexible as wax. When pure and freshly prepared it is colourless, transparent, and amorphous, but after a time it becomes yellow, and coated over with a hydrated white crust.

Phosphorus is insoluble in water, but soluble in ether, alcohol, sulphuret of carbon, and oils.

Phosphorus is an exceedingly violent *poison*, and is, for this reason, frequently employed for the extirpation of rats and mice. The rat paste, as it is called (phosphorus dough), is composed of 1 drachm of phosphorus, 8 ounces of hot water, and 8 ounces of flour.

140. *Experiments with Phosphorus.*

Experiment a.—Put into a small flask first a quarter of an ounce of ether, then a piece of phosphorus, of the size of a pea. Cork the flask and let it stand some days, frequently shaking it. Decant the liquid; it contains in solution about one grain of phosphorus, and will serve for the following experiments.

Experiment b.—Pour some drops of this solution upon the hand, and rub them quickly together; the ether will evaporate in a few moments, but the phosphorus will remain upon the hands in a state of minutest division. The more finely it is divided, so much the more easily does it combine with the oxygen of the air. During this combination it diffuses a white smoke and a *strong light* (it phosphoresces), causing the hands to shine in the dark; hence its name, *phosphorus*, from φῶς, *light*, and φέρειν, *to carry*. On rubbing the hands this light becomes more vivid, as a fresh surface of phosphorus is thus continually presented to the oxygen of the air. The heat thus evolved is too feeble to occasion ignition. This oxidation, taking place at a low temperature, is called *slow combustion*. The hands, during the phosphorescence, have a smell of garlic, and impart at the same time a sour taste to the tongue, as the combination of the oxygen with the phosphorus is an acid; it is called *phosphorous acid*, and consists of one atom of phosphorus and three atoms of oxygen. When a larger quantity of acid is required, put a stick of phosphorus into a flask, and let it remain in the cellar until the phosphorus is converted into a colourless acid liquid. In this case, a portion of the phosphorous acid produced takes up still more oxygen, and becomes phosphoric acid; accordingly, the liquid thus obtained is a mixture of these two acids.

Experiment c.—Moisten a lump of sugar with the solution of phosphorus, and throw it into hot water. The heat of the latter volatilises the ether and the phosphorus, both of which rise to the surface of the water and there inflame spontaneously on coming in contact with the oxygen of the air. The combustion in this case is brisk and complete. The phosphorus takes up a large quantity of oxygen, one atom of it uniting with five of oxygen; there is formed *phosphoric acid*, which is always generated when phosphorus is completely burnt, that is, with a flame, as has already been explained.

Experiment d.—Pour some of the ethereal solution of phosphorus upon fine blotting-paper; the latter *ignites spontaneously* after the ether has evaporated. The more minutely the phosphorus is divided, so much the more readily it begins to burn.

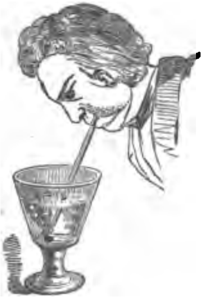
Experiment e.—Put a piece of phosphorus of the size of a pea on blotting-paper, and sprinkle over it some soot or pulverised charcoal; it melts after a while, and spontaneously *inflames*. The finely pulverised charcoal causes this combustion, owing to its porosity. It eagerly absorbs oxygen from the air, imparts it again to the phosphorus, and, being a bad conductor of heat, the cooling of the latter is prevented.

141. Phosphorus is also *easily ignited by friction*, and is, for this reason, employed in the manufacture of lucifer-matches. The combustible mass is prepared from hot mucilage, at 158° F. (70° C.), to which small pieces of phosphorus are added, being thoroughly incorporated with it by constant rubbing till cold. But as the mass, by becoming hard on drying, prevents the access of air to the phosphorus, there must be added some substance rich in oxygen, as black oxide of manganese, nitre, or red-lead, from which the phosphorus can abstract the oxygen neces-

sary for its ignition. 1¾ parts of phosphorus, 4 of gum Arabic, 4 of water, 2 of nitre, and 2 of red-lead, form a good inflammable mass. A temperature of 149° F. (65° C.)—158° F. (70° C.) is requisite for kindling matches (§ 113); in this case the temperature is caused by friction. The coating of the match is thus broken and kindled, and the continued burning is now maintained by the oxygen of the air.

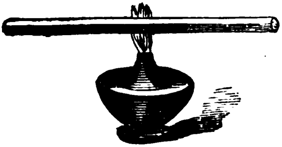
142. *Experiment.*—Put a piece of phosphorus, of the size of a pea, into a wine-glass, and pour hot water upon it until the glass is half filled; the phosphorus melts, but does not ignite, as access of air is prevented by the water. But if air be carefully blown by the mouth through a long glass tube upon the bottom of the wine-glass, *combustion* will ensue, which is visible, especially in the dark. In this case, as but little oxygen at a time comes into contact with the phosphorus, a still lower combination of phosphorus with oxygen is formed; it swims as a red powder in the liquid, and is called *oxide of phosphorus,* containing for every two atoms of phosphorus only one atom of oxygen.

Fig. 81.



143. *Experiment.*—We obtain the same combination by gently heating a piece of phosphorus of the size of a pea, placed in the middle of a glass tube, about twelve inches long. When ignition commences, remove the lamp. While the tube is held horizontally, the combustion is feeble and imperfect, because the heavy smoke, consisting of phosphoric and phosphorous acids, passing off slowly, allows the admission of only a small quantity of air. Some red oxide of phosphorus is deposited on the upper part of the tube. But the combustion immediately becomes more vivid on inclining the tube, and when the tube is held perpendicularly it is complete, as then the draught of air is most powerful. In this way phosphorus may be oxidised to either degree required; it must be slowly burnt to form phosphorous acid, imperfectly to form oxide of phosphorus, and completely to form phos-

Fig. 82.



phoric acid. The experiment is also well adapted for illustrating the principle of draughts in chimneys, &c. (§ 111.)

144. Phosphorus was formerly obtained from urine, but is now universally prepared from bones. Bones consist of gelatine, lime, and phosphoric acid ($P\ O_5$).

The *gelatine* is removed by calcining the bones. It is burnt.

The *lime* is removed by sulphuric acid. Sulphate of lime is formed.

Phosphoric acid. { The *oxygen* (O_5) is expelled by igniting the bones with charcoal (carbonic acid gas is disengaged).
Phosphorus (P) remains behind.

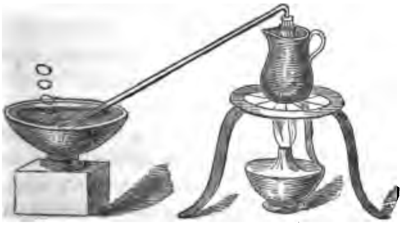
As phosphorus is volatile and highly inflammable, the phosphoric acid and charcoal are heated in a closed vessel, commonly in an earthen retort, the beak of which dips under water contained in the basin, in which the vapour of the phosphorus is to be condensed. This process is accordingly one of distillation. The carbonic oxide, which is simultaneously evolved, together with some phosphuretted hydrogen and carburetted hydrogen gas, escapes through the water.

Charcoal, at a red heat, has the power of abstracting oxygen from almost all acids and bases, as in this case from phosphoric acid, or, chemically speaking, to *deoxidate* or *reduce* them; thus carbonic oxide ($C\ O$), which escapes, is formed from carbon and oxygen. Almost all metals are obtained from native metallic oxides or ores, by heating them with charcoal.

PHOSPHURETTED HYDROGEN ($P\ H_3$).

145. *Experiment.*—Put into an ounce flask a quarter of an ounce of slaked lime, and a piece of phosphorus the size of a pea, fill it up to the neck with water, and place it in a small vessel containing a strong solution of salt, prepared by adding half an ounce of common salt to an ounce and a half of water. Fit to the flask a bent glass tube, one end of which is made to dip into a basin of water; heat the salt water to boiling, and a gas will be evolved, which,

Fig. 83.



as it issues from the tube and comes in contact with the air, *takes fire spontaneously*. This gas is called *phosphuretted hydrogen*, and consists of several combinations of phosphorus and hydrogen, chiefly of $P\ H_3$. If you collect it in a small jar filled with water, it immediately takes fire upon the admission of air. Both the phosphorus and the hydrogen combine with the oxygen of the air, and there results phosphoric acid ($P\ O_5$) and water ($H\ O$). The first rises as a white smoke, which, when it issues in separate bubbles from the water, takes the form of a wreath. Phosphuretted hydrogen, when unburnt, emits the smell of garlic.

146. In the preparation of sulphuretted hydrogen (§ 132), the iron deprived the water of its oxygen, and the sulphur took the liberated hydrogen. What these two substances together accomplish, phosphorus can effect alone; it abstracts from the water both its oxygen and hydrogen, and it divides itself between the elements of the water. The phosphorus forms with oxygen two acids, phosphoric and hypophosphorous acids, which remain behind; but it forms with hydrogen a volatile gaseous combination, which escapes. Phosphorus, however, can only effect this in the presence of a strong base, for instance, lime, with which the acids composed of phosphorus and oxygen combine. Thus, lime does not directly aid in the decomposition of water, but it encourages the phosphorus to exert more power and activity. The lime would gladly have combined with acids, but there are none present; they may, however, be formed, if the phosphorus abstracts the oxygen from the water. This does take place, and we can say the lime urges on the phosphorus,—disposes it to decompose the water, in order, as it were, to satisfy its own eagerness to unite with an acid. Thus is defined the name which this kind of affinity has received; it is called *predisposing affinity*. This term expresses an affinity, an eager desire to combine with a body not yet existing, but which body may be formed from the elements present, and which is in reality formed in consequence of this desire.

147. If we now reflect upon the processes of preparing hydrogen (§ 84) and sulphuretted hydrogen (§ 132), we shall see that in both of these instances a predisposing affinity is also exerted. But the impelling body, in these instances, is an acid, —the powerful sulphuric acid. This acid has a strong desire to unite with a base, and it urges the iron to convert itself into a base, which is readily accomplished when the iron combines with

the oxygen of the water. The other element of the water is thereby set free, and escapes as a gas, in the first case alone, in the second accompanied by sulphur, which the iron releases at the moment when it combines with the oxygen, for which it has a preference.

148. It may, perhaps, be asked why the sulphuric acid did not immediately combine with the metallic iron, or the lime with the phosphorus; this could not take place, as *simple substances, with but few exceptions, combine only with simple ones, and compound only with compound substances.* Hence the compound, sulphuric acid, cannot combine with the simple element, iron, but can combine with the compound, protoxide of iron. Neither can the compound, lime, enter into combination with simple phosphorus; but it will do so immediately, when phosphorus, by combining with oxygen, becomes a compound body.

149. In the last experiment, the flask was placed in salt water, in order to guard against the ignition of the phosphorus, in case the flask should accidentally break. Salt water, at the strength specified, will not boil under 228° F. (109° C.); consequently, the boiling in the flask is more active than if it had been placed in pure water, the temperature of which, under ordinary pressure, can only be raised to 212° F. (100° C.) The apparatus for heating substances by means of hot water or saline solutions is called a *water* or *saline bath.* By such contrivances extracts are evaporated, and substances dried, which, at a stronger heat, would easily burn, or otherwise be decomposed.

Phosphorus and sulphur are especially characterised by their great inflammability; hence they may be called *pyrogens* or *fire-generators.*

RETROSPECT OF THE PYROGENS (SULPHUR AND PHOSPHORUS).

1. Simple bodies combine only with simple bodies, compound only with compound bodies.
2. In order that two bodies may act chemically on each other, one of them must, as a general rule, be liquid or gaseous.
3. When a body is suddenly precipitated from its liquid or

gaseous state, as a solid, it is then obtained as a fine dust (milk of sulphur and flowers of sulphur).

4. All finely divided and porous bodies eagerly absorb gases, and condense them within their pores; in many cases this is done so powerfully as to force the gases into chemical combination (spongy platinum, charcoal, and soot).

5. *Imperfect combustion* or oxidation takes place when the supply of air is deficient; *slow combustion*, when substances combine with oxygen at the common temperatures: but *complete and rapid combustion*, when the union takes place at a high temperature, and with an abundant and constant supply of air. In the two former cases, lower degrees of oxidation are formed, and in the latter, higher degrees of oxidation.

6. In chemical reactions *the right of the strongest prevails;* a stronger chemical substance can expel a weaker from its combination, and replace it. This is called decomposition by *simple elective affinity.*

7. *Decomposition by double elective affinity* takes place when two combinations mutually exchange elements.

8. If single or double elective affinity is caused by the presence of a third body, commonly a strong acid or a strong base, it is called *predisposing affinity*.

9. *Deoxidate*, the opposite of *oxidate*, is a term applied to the depriving compounds of their oxygen.

10. In order to detect a chemical substance, and to separate it from others, the solution of it is mixed with tests, that is, with such bodies as form with it an insoluble compound (precipitate), or change its colour, smell, &c.; such changes are called *reactions.*

11. *Taste* is perceived only in soluble bodies, *odour* only in volatile ones.

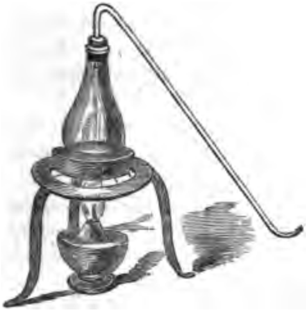
THIRD GROUP OF METALLOIDS: HALOGENS.

CHLORINE (Cl).

At. Wt. = 36.—Sp. Gr. = 2.5.

150. *Experiment.*—Pour one ounce and a half of muriatic acid upon a quarter of an ounce of finely powdered black oxide of manganese, and heat it gradually in a flask, to which is

Fig. 84.



adapted a bent glass tube; a yellowish-green gas is disengaged, which is collected by a process already described. This gas is called *chlorine* (from χλωρός, *green*), because it has a greenish colour. Fill with it several six-ounce bottles of white glass, and cork them up. Fill, likewise, a bottle with two-thirds of chlorine and one-third of water, and shake it up; suction is exerted upon a finger which closes the mouth of it,—a proof that a vacuum has been produced. If the finger be removed, the air immediately rushes in. This vacuum was caused by the chlorine having dissolved in the water, which might be inferred also from the disappearance of the yellow colour from the upper part of the bottle. One measure of water dissolves two measures of chlorine. This solution is called *chlorine water*.

Muriatic acid, which is usually prepared from common salt, is a combination of chlorine and hydrogen, and belongs to the class of hydrogen acids; if it be deprived of the hydrogen, the chlorine is set free. This is done in the following manner. When muriatic acid is added to black oxide of manganese ($Mn\ O_2$), the oxygen of the manganese takes from the muriatic acid its hydrogen, and *water* is formed, but simultaneously also perchloride of manganese ($Mn\ Cl_2$), from the manganese and chlorine liberated. The perchloride of manganese, however, loses at a very gentle heat half of its chlorine, just as the oxygen escaped from the black oxide of manganese at a red heat, only it loses it far more readily. From perchloride of manganese, there is accordingly formed protochloride of manganese and free chlorine, the latter of which escapes as a yellowish gas. $Mn\ Cl_2$ is resolved into $Mn\ Cl$ and Cl.

If the oxygen of the manganese is previously expelled by heat, and then conducted into muriatic acid, it no longer possesses the power of withdrawing from the acid its hydrogen, and consequently no chlorine will be evolved. Oxygen has this power only at the very moment when it is separating from its combination with another body, that is, in its *nascent state*. When actually liberated, it has far less inclination to abandon its freedom. This peculiarity appertains to other elements, and it is often taken advantage of to force into combination such bodies as have but slight affinity for other bodies, and which combination could not have been effected in a direct way.

Chlorine is not only obtained from manganese, but from all bodies which part easily with their oxygen, as, for instance, chlorate of potassa, red lead, &c., by heating them with muriatic acid.

151. Muriatic acid derives its chlorine from common salt, more than half of which consists of chlorine; consequently, this gas may be also obtained from salt by mixing three-quarters of an ounce of it with half an ounce of black oxide of manganese, two ounces of sulphuric acid, and one ounce of water, and heating them; by adding sulphuric acid to the salt, muriatic acid is formed, and set free, and this is decomposed by manganese, in the way already mentioned.

Chlorine acts as a *poison* on being inhaled; hence, *care must be taken not to inhale it* while preparing it. For greater security, pour some drops of alcohol and ammonia upon a cloth and wave it frequently in the air; the chlorine contained in the air will then be so altered, that it will lose its injurious properties.

152. *Experiments with Chlorine.*

Experiment a.—In order to recognise the odour of chlorine, smell cautiously chlorine water (but not the gas); the chlorine water may be tasted also without danger. The smell of chlorine is peculiarly pungent and suffocating, and it has an astringent, harsh, styptic taste.

Experiment b.—If a flask containing chlorine gas be exposed to the air, no diminution of the chlorine will be perceptible; but if the flask be inverted it will contain in a short time only atmospheric air. Chlorine is two and a half times *heavier* than common air, and its specific gravity is 2.5.

Experiment c.—Introduce a piece of litmus-paper into chlorine gas, and it becomes white; pour chlorine water upon red wine, or ink, and both the liquids will lose their colour.

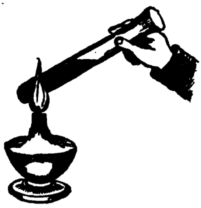
Chlorine bleaches and destroys all colours derived from the animal or vegetable kingdom. In consequence of this property, chlorine has become a most important agent in bleaching; and linen, cotton, paper, and other materials, may now be rendered perfectly white by it in a few hours; while, by the old method of laying them on the grass in the sun, weeks, and even months, were required for effecting it. This method of bleaching is called *quick bleaching*, the other is called *grass-bleaching*. The modern method is very excellent, and does not in the least injure the strength of the fabric, provided all the chlorine be completely removed again after the bleaching is finished, which is not so easily done as many bleachers suppose. If this precaution is not observed, or if the chlorine water is too strong or in excess, then, indeed, after the colour is destroyed, the fibres of the yarn or fabric itself will be attacked. The fault is not to be attributed to the chlorine, but rather to the injudicious application of it. A salt has lately been introduced into commerce, under the name of antichlorine, by means of which, if any chlorine should happen to remain in the bleached materials, they will not be in the slightest degree injured by it. As the health of the labourers is endangered by the use of chlorine gas or chlorine water, *chloride of lime* is now substituted, a salt in which chlorine is chemically combined, but from which it is easily disengaged, even by mere exposure to the air.

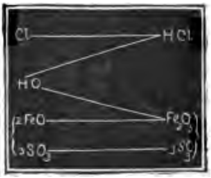
Experiment d.—Apply chlorine water to decaying and nauseous substances (water in which flowers have been kept, manure, rotten eggs, &c.); the bad odour will at once entirely vanish. Thus it not only *decomposes* colours, but also the *volatile combinations* formed during putrefaction, and which occasion disagreeable odours. It acts in a similar manner also upon morbific matter (matters of contagion, miasm), which, being diffused in the air or attached to clothes and beds, may communicate disease. Chlorine is, therefore, a powerful *disinfecting agent*, and is used for purifying all putrefying matter and infected atmospheres, and for arresting the decay of organic substances. Musty casks may also be purified by washing them first with chlorine water, and then with some milk of lime. Mouldy cellars, in which milk or beer cannot be kept without turning sour, are again rendered serviceable for a long time by fumigating them with chlorine gas, or by washing them with chlorine water, or a solution of chloride of lime.

Experiment e.—Fill a small bottle with chlorine water, and invert it in a vessel filled with water; if this is put away in a dark place, it remains unchanged; but if it is exposed to the sun, a colourless gas will collect in the upper part of the flask, in which a glowing taper will inflame; this gas is oxygen. After some days the water will entirely lose its odour of chlorine, and will have acquired a sour taste, and instead of bleaching blue litmus-paper, it will redden it. Three elements only were present, the constituents of water and chlorine; thus it is obvious, that the chlorine must have united with the hydrogen of the water to form muriatic acid, the oxygen being set free. Chlorine had here the choice between hydrogen and oxygen; it chose the former; it has, consequently, *a greater affinity for hydrogen* than for oxygen. This affords another example of simple elective affinity. Bottles in which chlorine-water is kept, should, therefore, be protected from the light, and this can be most conveniently done by pasting black paper round them.

The bleaching and disinfecting power of chlorine is now easily explained by its strong affinity for hydrogen. All animal and vegetable substances contain hydrogen, which is taken from them by chlorine. But if a single chemical pillar falls, the whole chemical structure tumbles with it. By the abstraction of the hydrogen, the colouring matter becomes colourless, the odorous principles scentless, the morbific matter innoxious, insoluble substances are very frequently rendered soluble, &c.

Fig. 85.





Experiment f.—Dissolve in a test-tube a small quantity of green vitriol (sulphate of iron) in cold water, and add to the solution a few drops of sulphuric acid; then, some chlorine water; the solution will immediately assume a yellow colour. In this case, also, the water is decomposed; the hydrogen passes to the chlorine, but the oxygen is not liberated, since it here meets with a body which already contains oxygen, but which is capable of receiving still more,—namely, protoxide of iron. This becomes more highly oxidised, and the yellow liquid now contains sulphate of sesquioxide of iron. Consequently we have in chlorine water a powerful *oxidising agent*, by means of which we can easily convert salts of the protoxide into salts of the sesquioxide or peroxide.

Experiment g.—Put into chlorine water some *pure* gold-leaf; it will soon disappear, as the simple element chlorine combines with the simple element gold. The combination is called chloride of gold; it is soluble in water. Chlorine has a very *great tendency to combine with the metals.* These combinations comport themselves like salts; they are called *metallic chlorides*, and most of them are soluble in water.

Experiment h.—Pour into a vessel filled with chlorine gas a little metallic antimony, in fine powder; it will fall in a red-hot state to the bottom, as though it were a shower of fire. The red heat is caused by the violent combination of the chlorine with the antimony. The white smoke which fills the flask is the new combination formed, viz., chloride of antimony. If a fine brass wire, on which a piece of tinsel has been fastened, be introduced into chlorine gas, the wire will burn with a vivid combustion, and with the emission of sparks. Here combustion means the same as a combination with chlorine. Brass consists of zinc and copper; accordingly, chlorides of zinc and copper are formed. Both dissolve in water, and the chloride of copper imparts to the solution a green tinge.

Experiment i.—Place in this solution a polished knife-blade; in a short time it will be covered with a coating of the red metal, copper. The iron possesses a still greater affinity for chlorine than copper does, and, as in chemical reactions, the right of the strongest prevails, so the iron seizes the chlorine, and the copper is deposited in the metallic state. This method is frequently employed for precipitating a metal from its solution. Polished iron is, accordingly, *a test for copper*, and by means of it we can ascertain, very simply and accurately, whether copper is present in pickled cucumbers, or preserved fruit, which may have been carelessly prepared in copper vessels.

153. *Experiment.*—If a piece of sodium of the size of a pea is thrown into a cup containing chlorine water, it will move rapidly round, just as in common water, with a hissing noise, and finally disappear; but if a sufficient quantity of the chlorine was present, the liquid will not afterwards give a basic reaction, as in the experiment in § 67; neither will it have an alkaline, but a saline taste. If allowed to evaporate gradually over a warm stove, small cubic crystals remain behind, the constituents of which are chlorine and sodium. Thus, from these two elements a *salt* has been formed, familiarly known as *common salt.*

154. Chlorine, like oxygen and sulphur, unites in several proportions with other substances. Thus, there are different chlorides, as well as different oxides and sulphurets. The combinations containing smaller quantities of chlorine are called *protochlorides;* those containing larger quantities are called *perchlorides.*

IODINE (I).

At. Wt. = 127.—Sp. Gr. = 5.

155. Iodine is a solid body, somewhat resembling black-lead; it smells a little like chlorine, has a pungent taste, and stains the skin brown.

Experiment.—Put 24 grains of iodine into a flask, and pour over them half an ounce of strong alcohol; if the iodine is pure it will entirely *dissolve.* This dark brown solution is called *tincture of iodine.* Water dissolves only a trace of iodine, but yet is rendered yellow by it.

Experiment.—Put a little iodine upon a knife, and hold it over the flame of a lamp; the iodine melts, and is afterwards converted into a *violet-coloured gas—vapour of iodine.* As the iodine fumes are nearly nine times heavier than common air, they sink in it. Iodine owes its name to the colour of its vapour, the Greek word ἰώδης meaning *violet-coloured.* The vapour appears more beautiful when the iodine is heated in a small flask. After cooling, the walls of the flask become lined with small brilliant crystals of solid iodine, affording an example that regular crystals may also be formed when bodies pass from the aeriform into the solid state.

Experiment.—Boil one grain of starch in a test-tube with one drachm of water, and add to the thin paste thus obtained a few drops of tincture of iodine; *the iodine combines with the starch; the combination is of a deep blue colour.* The blue colour disappears on boiling, but returns again on cooling. If one drop of the starch paste is mixed with one quart of water, even at this extreme dilution, the iodine tincture will impart to it a violet tinge. Consequently, it is an exceedingly delicate test for detecting starch, and starch, on the other hand, for detecting iodine. If a little tincture of iodine is dropped upon flour, bread, potatoes, &c., the presence of starch in these substances will at once be indicated.

BROMINE (Br).

At. Wt. = 80.—Sp. Gr. = 3.

156. Bromine is a deep brownish-red, heavy, and very volatile liquid. Its name is derived from the Greek word *βρῶμος*, signifying a disagreeable odour. Bromine, at common temperatures, emits yellowish-red fumes, which have a penetrating and offensive odour, resembling that of chlorine. It produces a yellow colour with starch.

Iodine and bromine have, in their relations to other bodies, *the greatest similarity to chlorine.* Like chlorine, they possess a strong affinity for hydrogen, and form with it acids; they also combine with the metals forming protiodides and periodides, protobromides and perbromides, which have all the properties of salts. If a polished silver plate be held over the fumes of iodine and bromine, it is coloured, first yellow, then violet, and then blue, owing to these vapours combining with the silver. This film of iodide and bromide of silver is decomposed almost instantaneously in the light, slowly in the shade, and not at all in the dark. On this property is founded the *Daguerreotype* process. Iodine and bromine are also used in medicine for dispelling tumors and goitres, and in the treatment of scrofula, &c.

Both of these two substances are faithful companions of chlorine; wherever common salt occurs, whether in the earth, the sea, or mineral springs, small quantities of them are present, not in a free state, however, but combined with metals. The different sea-weeds attract these combinations from the sea-water, and from these sea-weeds iodine and bromine are extracted. Both of these bodies have poisonous properties.

FLUORINE (Fl).

At. Wt. = 19.

Fluorine is likewise an element having similar properties to chlorine, but it is unknown in its isolated state. The mineral known as fluor-spar, crystallising in tubes, consists of fluorine and calcium.

CYANOGEN (C_2 N or Cy).

At. Wt. = 26.—Sp. G. = 1.8.

157. *Prussian-blue*, universally used as a pigment, consists of iron, carbon, and nitrogen. But both the two latter substances are so closely combined with each other, that they may be regarded as one. The most striking thing in this combination is, that, although a compound, it combines with other elements, *exactly in the same manner as though it were itself an element.* For this reason, under the name *cyanogen*, it is here included among the elements. It forms an exception to the previously mentioned rule, that simple bodies can only combine with simple, and compound only with compound bodies. Cyanogen comports itself towards other bodies in *a manner similar to that of chlorine, iodine, bromine, and fluorine*; it is gaseous, and, like these, forms with hydrogen an acid—the poisonous prussic acid, and, like them, also unites with metals, forming protocyanides and percyanides. The compounds of cyanogen have likewise the characters of salts. The combination of cyanogen with iron, as already stated, is of a beautiful blue colour, and hence the name *cyanogen*, from the Greek word *κύανος*, *blue.*

The five metalloids, chlorine, iodine, bromine, fluorine, and cyanogen, are characterised as follows:

1. They have a far greater affinity for hydrogen than for oxygen. They combine with the latter only on compulsion (oxygen acids).

2. Their combinations with hydrogen are acids (hydrogen acids).

3. Their combinations with the metals are salts. These salts are called *haloid salts*, to distinguish them from the common or *oxygen salts*, which consist of an acid and a base.

On account of this latter peculiarity these elements have been called *halogens*, or *salt producers*.

RETROSPECT OF THE HALOGENS (CHLORINE, IODINE, BROMINE, FLUORINE, AND CYANOGEN).

1. Crystals may be formed, 1st, from a *solution*, either by cooling (saltpetre), or by evaporation (common salt); 2nd, from a *melted* fluid, by congelation (sulphur); and, 3rd, from *vapour*, when it becomes solid immediately on cooling (snow, iodine).
2. The crystallised or regularly formed bodies are the reverse of the *amorphous* bodies, in which no definite form is to be perceived (vitreous and pulverulent bodies). Many bodies can assume two, or even several, different forms, and are then called dimorphous or polymorphous bodies (charcoal, sulphur).
3. Water can dissolve, not only solid, but gaseous bodies; for instance, chlorine, sulphuretted hydrogen, &c., and the more of them the colder it is.
4. Not only heat, but light also, may effect or destroy chemical combinations.
5. A body has a greater inclination to combine with another body at the very moment when it is separated from a combination (nascent state).
6. There are, also, by way of exception, compound bodies, which, just as if they were chemical elements, can combine with simple bodies (cyanogen).

FOURTH GROUP OF METALLOIDS: HYALOGENS.

BORON (Bo),
At. Wt. = 11, and
SILICON (Si),
At. Wt. = 21.

158. Both of these substances occur, in nature, only in combination with oxygen; boron but seldom, as in boracic acid or borax; and silicon very abundantly, as in sand, quartz, and almost all other stones. The word *silicon* is derived from the Latin *silex*, flint; hence its symbol, Si. Boracic and silicic acids form, with many bases, amorphous salts (glass,

slag, glaze); for this reason, boron and silicon may be called *hyalogens* or *glass producers.*

RETROSPECT OF THE NON-METALLIC BODIES, OR METALLOIDS.

1. The thirteen substances now treated of are called *non-metallic bodies,* or *metalloids,* because they do not possess a metallic appearance.

2. Heat and electricity pass through them very slowly; they are *bad conductors* of heat and electricity. The metals, on the contrary, which give rapid transit to those forces, are good conductors.

3. On decomposition by *galvanism,* the metalloids always separate at the positive pole (the zinc side), and the metals at the negative pole. As the positive pole only attracts bodies endowed with the opposite or negative electricity, and the negative pole only those endowed with positive electricity, so the metalloids are called *electro-negative* bodies, and the metals *electro-positive* bodies.

4. Almost all the metalloids combine with *hydrogen,* but, as a general rule, the metals do not. Some of the hydrogen combinations have acid properties (*hydrogen acids*).

5. In the same manner, the metalloids combine with oxygen, forming acid-oxides or *oxygen acids.* The metals also combine with oxygen, but forming mostly oxides or *bases.*

6. The following are the states of aggregation of the metalloids at the ordinary temperature:

7 metalloids, solid: C, S, P, Se, I, B, Si.
1 " fluid: Br.
5 " gaseous: O, H, N, Cl, (Cy).

7. They form four families or groups, founded on their resemblance to each other:

1st group, Organogens, animal and plant producers: O, H, N, C.
2nd " Pyrogens, fire producers: S, P, Se.
3rd " Halogens, salt producers: Cl, I, Br, Fl, (Cy).
4th " Hyalogens, glass producers: Bo, Si.

ACIDS.

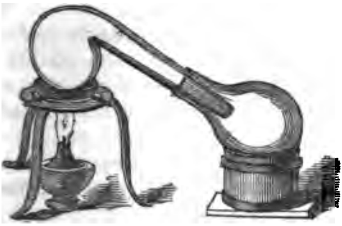
FIRST GROUP: OXYGEN ACIDS, OR COMBINATIONS OF THE METALLOIDS WITH OXYGEN.

NITROGEN AND OXYGEN.

1.) *Nitric acid*, or aquafortis ($H\,O, N\,O_5$).

159. *Experiment.*—Introduce into a small retort half an ounce of powdered saltpetre and half an ounce of common sulphuric acid, and let the retort stand erect for some time, in order that as much as possible of the sulphuric acid remaining in the neck may flow down into the retort. Then surround the latter with sand contained in an iron vessel, adapt to the beak of it a receiver, wrap round the joint some strips of moistened blotting-paper, and heat gently. In a short time a yellowish fuming fluid passes over into the receiver, which is placed in a vessel filled with water, and must frequently be sprinkled with cold water; this fluid is heavier than water, and is called *nitric acid*.

Fig. 87.



Saltpetre is a salt, consisting of nitric acid and a base. The base is called oxide of potassium, or more briefly potassa, and has for its symbol K O. Sulphuric acid is a stronger acid than nitric acid; that is, it has a greater affinity than the latter for potassa; it therefore expels the nitric acid, which, by the application of heat, is converted into vapour, but is condensed again in the receiver as a fluid. A quarter of an ounce of sulphuric acid would, indeed, have been sufficient to expel all the nitric acid, but the process is conducted much more easily when double the quantity is employed. This explains why the saline residuum left in the retort has still a very acid taste; it is called *bi*sulphate of potassa. If only one-half of

Volatile.

Non-volatile.

the sulphuric acid had been employed, *neutral* sulphate of potassa would have remained behind.

Nitric acid has the same constituents as common air, but in different proportions. The air contains for every four measures of nitrogen one measure of oxygen; nitric acid, on the contrary, contains ten times more of the latter element; consequently, for every four measures of nitrogen, ten measures of oxygen; or, what is the same thing, for every two measures of N (1 atom), five measures of O (5 atoms). These two gases are only mechanically mixed together in the air, but in the nitric acid, on the contrary, they are chemically combined. This is a striking example how wonderfully the properties of bodies change, when they chemically combine with each other. When mechanically mixed together, the constituents of nitric acid form a life-sustaining gas, while, when chemically combined, they form one of the most corrosive fluids.

It might, perhaps, be supposed that nitric acid could be formed more directly and simply from the air; but this cannot be done, because the inert nitrogen will not voluntarily combine with oxygen; this combination can only be effected by a circuitous method, which will be described hereafter.

The strongest nitric acid contains in every pound two and a quarter ounces of water, or in each atom of acid one atom of water, without which latter it cannot exist; if this is withdrawn from it, it is resolved into oxygen and a lower oxygen-compound of nitrogen. Many other bodies, especially organic bodies, behave in a similar manner. This water has been called *water of constitution*, denoting thereby that it is indispensably necessary to the constitution—to the existence—of the bodies referred to. The water of crystallisation is necessary only to the continuance of the *form* and *shape* of the crystals. The crude nitric acid of commerce, which is commonly prepared in large iron cylinders, contains, perhaps, from ten to twelve ounces of water in the pound; consequently it is three or four times weaker than the above.

160. *Experiments with Nitric Acid.*

Experiment a.—A drop of nitric acid is sufficient to acidify several spoonfuls of water, and even at a greater dilution it will redden blue litmus-paper; nitric acid is accordingly distinctly characterised as an *acid*.

Experiment b.—The well-known volatile alkali, more correctly called ammonia, may serve as the antithesis to the acids. It has an alkaline taste, has no action on blue test-paper, but turns red test-paper blue; it has the character of a *base*. Its exceedingly pungent odour is also remarkable.

Experiment c.—Add carefully, and by drops, some nitric acid to half an ounce of ammonia, until the colour of red or blue test-paper remains unchanged by it. When this point is attained, you will no longer perceive either the acid or the alkaline taste or smell. The taste has become *saline*, the smell has vanished. This process, as already mentioned, is called *neutralisation*. Upon evaporating the solution a white *salt* remains behind, nitrate of ammonia. By appropriate means, the nitric acid, as well as the ammonia, may be again liberated from this salt.

It is characteristic of all acids, that *they combine with bases, forming entirely new bodies, called salts*, and thus lose their acid properties.

Experiment d.—If lead be heated for a long time in the air it abstracts oxygen from it, and becomes converted into a reddish-yellow powder, called oxide of lead, or, popularly, litharge. Take up a small portion of this litharge on the point of a knife, put it into a test-tube, and add some nitric acid. The greater part will be dissolved by gentle heating. Filter the solution while warm, and put it in a cold place; a salt will be deposited from it in white brillant crystals; this is nitrate of oxide of lead. This shows that oxide of lead is also a base, as it combines with acids forming salts. This salt is soluble in pure water.

Nitric acid dissolves most of the metallic oxides, and forms with them salts, all of which are soluble in water. For this reason, nitric acid is often used for cleaning metals, for instance, copper and brass instruments, which, during the process of annealing, soldering, &c., have become covered with a coating of oxide.

Experiment e.—Pour over some shot common nitric acid, slightly diluted with water; a solution is also effected in this instance, but it is accompanied by the evolution of a yellowish-red vapour of a suffocating smell. This vapour is called nitrous acid, and contains, as its name implies, less oxygen than nitric acid. The missing oxygen has united with the lead, and has converted it into an oxide. Part of the nitric acid is decomposed, while another part of it combines with the oxide, and forms the same salt, as in the former experiment. This likewise crystallises from its solution, if it is evaporated until a film forms on its surface.

In this case nitric acid exerts, as we see, a double action; it first oxidises the lead, and then combines with the oxide formed. The lead is apparently dissolved, but it is obvious that this is quite a different kind of solution from that of common salt or sugar in water. The salt and sugar are unchanged in the solution, while the lead is not contained in the liquid as a metal, but as a salt, a nitrate. The same thing occurs with all other metals which are soluble in nitric acid; as, for example, with silver, mercury, copper, iron, &c. Gold is not dissolved by it; hence it may be separated from silver by means of nitric acid.

Experiment f.—The metalloids, as well as the metals, are oxidised by nitric acid; charcoal, on being boiled in it, becomes carbonic acid; sulphur, sulphuric acid; phosphorus, phosphoric acid; &c. In all these cases yellowish-red fumes of nitrous acid are evolved.

Experiment g.—Organic substances also, as wool, feathers, wood, indigo, &c., are oxidised and decomposed by heating them with nitric acid. This sort of decomposition may be regarded as combustion in the moist way. If organic substances are allowed to remain for a short time only in contact with this acid, they will assume a yellow colour, owing to the evolution of nitrous acid. In this manner wood may be stained, and silk may be dyed yellow; the hands and clothes are also stained yellow by nitric acid. Cotton undergoes a most remarkable change if soaked for a short time in the *strongest* nitric acid; it will then detonate and explode, like gunpowder, only far more violently. (§ 433.) Strong nitric acid is partially decomposed, and coloured yellow, by the rays of the sun.

If you colour some water blue in a test-tube with one drop of solution of indigo (§ 173), and add to it on boiling one drop of nitric acid, the blue colour will disappear. This reaction serves for the detection of nitric acid.

Nitric acid, as the preceding experiments show, is *very easily decomposed*, and with the liberation of oxygen, which, in the nascent state, has the greatest desire to combine again with other bodies. It is, owing to this property, one of the most important *means of oxidation*.

Experiment h.—The nitrates, also, are easily decomposed. Having powdered some of the nitrate of lead, obtained in experiment *d* or *e*, throw it upon a red-hot coal; decomposition will ensue, with the emission of sparks, and globules of metallic lead will remain beyond. The nitric acid is here completely resolved into nitrogen and oxygen; the latter, as well as the oxygen of the oxide of lead, combines with the coal, forming carbonic acid, which, together with the nitrogen that has become gaseous, quickly escapes and occasions the emission of sparks. This sudden evolution of gases from a solid body is called *detonation*.

2.) *Nitrous Acid* (NO_3).

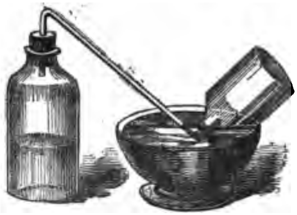
161. This acid is always produced as a disagreeable secondary product from nitric acid, when this, as in the previous experiment, is employed for dissolving or oxidising metals or other substances. At the common temperature it forms a *reddish-yellow suffocating vapour*, which at a very low temperature may be condensed into a blue liquid. As the inhalation of these vapours is injurious to the lungs, experiments performed with this acid should always be so arranged that they may be carried off by a draught.

Fuming Nitric Acid.—Nitric acid will dissolve large quantities of the above-mentioned nitrous acid vapour, and is thereby converted into a reddish-yellow liquid, which in open vessels gives off the same coloured fumes. It is then called *fuming nitric acid* ($NO_3 + NO_5$). On dilution with water it becomes, first green, then blue, and finally colourless, while the nitrous acid escapes.

3.) *Nitric Oxide* (NO_2).

162. *Experiment.*—Pour over a halfpenny, placed in a wide-mouthed bottle, a little water, and then add by degrees some nitric acid, until a brisk effervescence ensues. This effervescence is caused by the evolution of a gas, which must be collected in a jar of white glass over the pneumatic trough. It is called *nitric oxide*, and consists of two measures (1 at.) of nitrogen and two measures (2 at.) of oxygen.

Fig. 88.



Close the mouth of the jar under water; it seems to be empty, for the nitric oxide is colourless; but if the jar be opened, and air be carefully blown in, then the jar becomes filled from above downwards with yellowish-red vapours. The nitric oxide takes thereby from the air one atom of oxygen, and is converted into nitrous acid, and $N O_2$ becomes $N O_3$. On account of this property, it has an important application in the preparation of common sulphuric acid. (§ 172.) It is here formed from nitric acid, because the copper withdraws from it three atoms of oxygen, and becomes an oxide, which combines with undecomposed nitric acid, forming nitrate of the oxide of copper. This salt is obtained in blue crystals by evaporating the solution of the halfpenny.

163. 4.) *Nitrous Oxide* ($N O$) is a combination of two measures (1 at.) of nitrogen with one measure (1 at.) of oxygen; it is a colourless gas, which, when inhaled, has an intoxicating effect, and is called also laughing gas. This gas may be regarded as atmospheric air, containing double its usual amount of oxygen.

By the following table it will be seen that both the volumes and the weights of the constituents of the four compounds just treated of are in regular proportion:

		In *Weight.*							In *Volume.*					
oz.			oz.											
14	N.	with	40	O,	or	2 vols.	(1 at.)	N.	with	5 vols.	(at.)	O,	to	$N O_5$.
14	—	“	24	—	“	2 “	(1 at.)	—	“	3 “	“	—	“	$N O_3$.
14	—	“	16	—	“	2 “	(1 at.)	—	“	2 “	“	—	“	$N O_2$.
14	—	“	8	—	“	2 “	(1 at.)	—	“	1 “	“	—	“	$N O$.

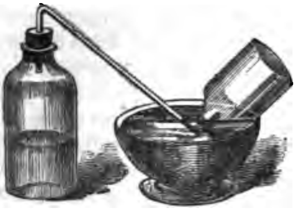
By one measure or atom of oxygen (O) is here meant 8 ounces, grains, &c., in weight. On the other hand, by two measures or one atom of nitrogen (N) is meant a quantity in weight of 14 ounces, grains, &c.

CARBON AND OXYGEN.

1.) *Carbonic Acid*, or *fixed air* ($C\ O_2$).

164. It has already been shown, when treating of carbon, that coal and all our combustible substances form, during brisk combustion, carbonic acid (§ 115), and that this gas may be detected by lime-water, which is thereby rendered turbid, owing to the formation of an insoluble salt, carbonate of lime. Chalk, limestone, and marble are also carbonates of lime, and from them carbonic acid may be prepared in large quantities.

Fig. 89.



Experiment.—Pour into an eight ounce bottle half an ounce of nitric acid and half an ounce of water, and then add some pieces of chalk or limestone. Adapt to the bottle a bent glass tube, and conduct the gas, which escapes with effervescence, into a jar placed over the pneumatic trough, and collect it, as was directed under oxygen. The stronger nitric acid expels the feebler carbonic acid, while it combines with the base, lime ($Ca\ O$). The nitrate of lime formed ($Ca\ O,\ N\ O_5$) is a soluble salt; therefore there remains in the bottle a clear liquid, from which, by evaporation, the nitrate may be obtained in a solid form.

Volatile.

Non-Volatile.

Experiment.—Repeat the experiment, but instead of nitric acid take half an ounce of sulphuric acid ($S\ O_3$), carefully diluted with two ounces of water (§ 84); you will obtain carbonic acid and sulphate of lime. The liquid in this case does not become clear, since the sulphate of lime ($Ca\ O,\ S\ O_3$) is a salt difficult to dissolve; it is the same substance as that commonly called gypsum, or plaster of Paris. Having finished the experiment, collect and dry the sulphate of lime, and preserve it for future experiments. The last two experiments are obvious examples of simple elective affinity.

Volatile.

Non-Volatile.

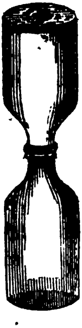
Experiment.—Add some sulphuric acid to the nitric acid solution of the first experiment; the clear liquid will become thick and turbid, sulphate of lime being likewise formed, because sulphuric acid, which is stronger than the nitric acid, expels the latter, and combines with the lime.

Easily soluble.
Difficultly soluble.

165. *Experiments with Carbonic Acid.*

Experiment a.—If moistened blue test-paper is exposed to carbonic acid it is reddened, but, on being left in the air for some time the blue colour is restored; carbonic acid is a *volatile acid.*

Fig. 90.



Experiment b.—A burning taper is extinguished when held in carbonic acid, and it is fatal to men and animals if they inhale it. Carbonic acid gas can *neither support combustion nor life.*

Experiment c.—Invert a jar filled with carbonic acid over one containing only atmospheric air; if after some moments you introduce into each of these jars a burning taper, that in the upper vessel will continue to burn, while that in the lower one will be extinguished. Carbonic acid is *heavier* than common air; it has sunk into the lower jar, while the atmospheric air has ascended into the upper one. If a bottle, filled with carbonic acid, be held with its mouth obliquely over the flame of a lamp, so that the gas can flow out, the light will be extinguished.

Experiment d.—Repeat the experiment with the two jars, filling, instead of the upper one, the *lower* one with carbonic acid. If, after some hours, you add lime-water to both of the jars, and shake them, you will obtain in both of them a precipitate of carbonate of lime,—a proof that the carbonic acid has partly ascended into the upper jar. Both gases have become intimately mixed, or the carbonic acid, though heavier, has ascended, and the common air, though lighter, has diffused itself downwards. This voluntary mixing of the different kinds of gases together is called *diffusion of gases.* This diffusion of gaseous bodies, since it maintains a constant equality and balance of the constituents of the atmosphere, is of great importance in the economy of nature, and accounts for the fact that the constitution of the air is everywhere nearly uniform, although in one place free oxygen is withdrawn from it, and in another place carbonic acid is added to it.

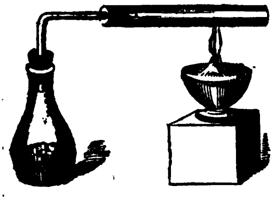
Experiment e.—Fill a bottle containing carbonic acid half full of pure water, close it with the finger, and shake it; the water takes up the carbonic acid, and, as a vacuum is formed, the finger is pressed into the mouth of the bottle by the external air. Carbonic acid gas is *soluble in water;* one measure of the latter will dissolve one measure of carbonic acid, but twice as much when subjected to pressure; it thereby acquires an acid taste, and the property of effervescing. Such waters ooze out from the earth in many places; for instance, at Selters and Bilin, and they are used for their medicinal qualities, under the name of *carbonated waters.* They are now also prepared artificially. From this it appears that carbonic acid is innocent when taken as a drink, but is injurious when inhaled. The effervescence of bottled beer and champagne is owing to carbonic acid, which is formed during the fermentation of these liquors, and kept confined in the bottles by corking them.

Experiment f.—Throw a piece of chalk into vinegar; vinegar is one of the weakest acids, yet it is able to expel carbonic acid. This escapes with effervescence. Carbonic acid is a *very feeble acid,* because it has a very great inclination to become gaseous.

Formerly carbonic acid was only known in its gaseous state; but in recent times it has been converted into a *liquid,* by strong compression at a low temperature. This liquid evaporates with such great rapidity, that a cold of nearly —212° F. (—100° C.) is produced. (§ 40.) By this means chemists have lately succeeded in rendering carbonic acid a *solid.* It then has the appearance of snow or ice.

166. *Experiment.*—To be perfectly convinced that carbon is contained in the colourless carbonic acid gas, take a test-tube, break the bottom of it, and adapt to it, by means of a perforated cork, a glass tube, and connect it with a bottle in which carbonic acid is evolved. (§ 164.) Introduce into the test-tube a piece of potassium of the size of a pea, previously dried between blotting-paper, and heat

Fig. 91.



the place where it lies with a lamp. Potassium is a metal very similar to sodium, and has, like it, an extraordinary affinity for oxygen; at the degree of heat produced by the lamp, it is enabled to withdraw the oxygen from the carbonic acid which passes over it. This takes place, and oxide of potassium, or, more simply, potassa ($K\ O$), is formed, one of the strongest bases, which immediately combines with a portion of the acid present, forming carbonate of potassa. This is coloured black by the separation of carbon. If you put the test-tube, containing the black saline mass, into a wide-mouthed bottle, in which there is some water, the carbonate of potassa will dissolve, but the carbon will float mechanically in the solution, and may be collected on a filter. The liquid has a basic reaction, since the feeble carbonic acid is not able fully to neutralise the alkaline properties of so strong a base as potassa. The presence of carbonic acid is proved by the effervescence produced on the addition of an acid.

Carbonic acid consists of one atom of carbon and two atoms of oxygen, and has consequently the formula $C\ O_2$. By weight, then, 6 ounces or grains of carbon are united with 16 ounces or grains of oxygen; accordingly, one atom of carbon is equal in weight to 6 ounces, grains, &c., of carbon.

167. Carbonic acid is everywhere unceasingly generated, and especially,—

a.) In those regions of the earth where volcanoes are active, or probably were active in a former age. It is generated at the Grotto del Cane, near Naples,—at Pyrmont, in Westphalia,—and in the neighbourhood of the Lake of Laache, &c.; and it oozes in a constant current from various *crevices* in different parts of the *earth.*

b.) In all ordinary *combustions*, as has already been mentioned several times.

c.) In the *respiration* of men and animals, as may easily be proved by blowing the air coming from the lungs through a glass tube into lime-water; carbonate of lime is formed, which renders the clear liquid turbid. We inhale oxygen; this combines in our bodies with carbon, and is again exhaled as carbonic acid; therefore, in those crowded apartments where many people congregate, or where many lights are burning, some arrangement should be made by which the vitiated air—that is, air rich in carbonic acid, may be conducted off, and be replaced by fresh air—that is, air rich in oxygen. This is accomplished by means of artificial currents of air, or ventilation.

d.) In the *fermentation* which occurs in the making of wine, beer and spirit. In this process the sugar is resolved into alcohol and carbonic acid; the former remains in the liquor, and imparts to it its intoxicating power, while the carbonic acid escapes in the air.

e.) In the decay and *putrefaction* of all animal and vegetable substances. Carbon is contained in all organic bodies; during decay it is gradually converted by the oxygen of the air into carbonic acid; hence, wherever plants and animals exist, whether upon the earth, in the sea, or in the air, carbonic acid must be formed.

All the carbonic acid thus formed is received into the air. Did it remain there, however, the air would become gradually deteriorated, more especially as, in the processes of breathing, combustion, and decay, free oxygen or vital air is taken from it. But this is not the case. The oxygen does not decrease. The carbonic acid does not increase. An inscrutable wisdom has appointed the vegetable kingdom as the protector of animal life, and, with wonderful simplicity, has provided that plants should absorb from the air, as their *principal means of support*, the carbonic acid exhaled, as useless, by men and animals, and should yield oxygen to them in return. Plants inhale carbonic acid, and (during the day) exhale oxygen.

Fig. 92.

Lime-water (§ 115) serves for the detection of carbonic acid. You may infer the presence of carbonic acid in solid bodies, if an effervescence unattended with odour is occasioned by dropping muriatic acid upon them.

2.) *Carbonic Oxide* (C O) has already been treated of. (§ 110.)

SULPHUR AND OXYGEN.

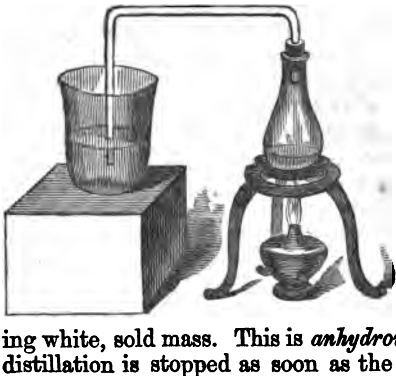
1.) *Sulphuric Acid* ($S O_3$).

168. What iron is to the machinist, sulphuric acid is to the chemist. As the former makes out of iron not only

machinery of all sorts, but also tools by which he can work up every other material, so sulphuric acid has also for us a double interest. It not only forms with the bases very important salts, but we employ it also as the most useful chemical means for producing numerous other chemical substances and changes, as has already been taught in the preparation of hydrogen, phosphorus, chlorine, nitric acid, carbonic acid, &c. Since it has come into general use for the cleaning of metallic implements, for the kindling of matches, and for making blacking, &c., it is well known as a sharp, corrosive fluid. It stands, as it were, the Hercules among the acids, and by it we are able to overpower all others, and expel them from their combinations. It occurs in commerce as a liquid only. There are two sorts: 1) an oily fuming liquid (Nordhausen sulphuric acid); and 2) another somewhat thinner, and not fuming, acid (common sulphuric acid, or oil of vitriol). But it may be obtained in a solid and dry state in the following manner:

169. *Anhydrous Sulphuric Acid.*

Fig. 93.



Experiment.—Pour into a small flask, placed in a sand-bath over a tripod (see Fig. 93), half an ounce of Nordhausen sulphuric acid, and heat it gently till it boils moderately. Conduct the vapour through a tolerably wide glass tube into an empty flask, which is placed in a vessel filled with cold water. In summer time the water may easily be made colder by adding a few tea-spoonfuls of powdered saltpetre. If the vapour be suffered to escape into the air, it appears in thick white fumes, having a pungent acid smell; but if conducted into the flask, it is condensed into a glistening white, sold mass. This is *anhydrous sulphuric acid.* The distillation is stopped as soon as the boiling ceases, and the glass tube becomes too hot for the hand to bear. What remains in the flask no longer fumes; it has become common sulphuric acid. To cause this to boil, you must apply a ten times stronger heat than before, for it does not begin to boil till above 572° F. (300° C.), while the anhydrous acid boils even at a little above 86° F. (30° C.) This is the reason why the boiling ceases when the latter has escaped.

Experiments with Anhydrous Sulphuric Acid.

Experiment a.—Take out some of the acid by means of a glass rod, and introduce it into a dry test-tube; it will fume violently, and after a time become fluid; *that is, it attracts water* from the air, and is thereby converted into Nordhausen sulphuric acid. On longer standing, it absorbs still more water, and ceases to fume; it thus becomes common sulphuric acid. By evaporation this water cannot again be removed, for the sulphuric acid will deliver this up only when we present to it a base in exchange.

Experiment b.—If anhydrous sulphuric acid be thrown into water, it is dissolved with a hissing noise and the *violent evolution of heat.*

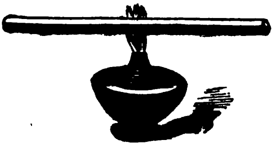
Experiment c.—It is likewise dissolved by common sulphuric acid, converting this into the fuming acid. Fuming sulphuric acid is accordingly a solution of the anhydrous in common sulphuric acid. Its constituents are, by weight, 16 of sulphur (1 atom) and 24 of oxygen (3 atoms). Hence its symbol $= S\,O_3$.

170. *Fuming Sulphuric Acid.*

This is obtained by the distillation of green vitriol, which, as is known, consists of sulphuric acid and protoxide of iron. (§ 89.)

Experiment.—Put a crystal of green vitriol into a glass tube, and heat it; aqueous vapour escapes, and the green crystal becomes white (anhydrous). On further heating the white colour passes into reddish-brown, and a little sulphurous acid is evolved; for a portion of the sulphuric acid gives up one atom of oxygen to the protoxide of iron, which it thus converts into sesquioxide, while the other portion combines with the sesquioxide of iron. If this basic sulphate of sesquioxide of iron be strongly and continuously heated, then the sesquioxide of iron releases the sulphuric

Fig. 94.



acid; and this escapes, and becomes anhydrous, because it no longer finds any water present. In preparing it on a large scale, earthen retorts are used, and the fumes are conducted into common sulphuric acid, which is thereby converted into the fuming acid. It is a thick, flowing liquid, like oil, and is called Nordhausen sulphuric acid, because this city supplied Germany with it for centuries. It has the specific gravity of 1.9, and every pound of it contains about 2 or 2½ ounces of water.

If this acid be exposed to the air, the anhydrous acid in it evaporates and unites with the watery vapour contained in the air; accordingly, common sulphuric acid is formed, which, being ten times less volatile, condenses in the cold air, forming white vapours, just as steam does. Consequently, the fumes of this acid consist of the vapour of common sulphuric acid.

As long as the process of manufacturing sulphuric acid from green vitriol alone was known, it was a very expensive article. A hundred-weight is now obtained for the same sum that was formerly paid for two pounds.

171. *Common Sulphuric Acid* ($H\ O,\ S\ O_3$).

Charcoal and phosphorus on burning take up the greatest quantity of oxygen with which they can combine, and we obtain carbonic and phosphoric acids. If sulphur did the same, nothing would be easier than to convert it into sulphuric acid. But sulphur, on burning, forms sulphurous acid ($S\ O_2$), that is, 16 parts in weight of sulphur (1 atom) combines with 16 in weight of oxygen (2 atoms). To convert this into sulphuric acid, it must be compelled to take up another 8 in weight of oxygen (1 atom). This is done by a body which is very rich in oxygen, and which likewise readily parts with it, namely, by nitric acid.

Experiment.—Fasten some pieces of sulphur to an iron wire, inflame and hold them in a capacious bottle containing a little water, until the blue sulphurous flame is extinguished; the bottle becomes filled with a white smoke, which is recognised by its odour to be sulphurous acid. (§ 64.) If you now introduce a shaving moistened with nitric acid into the vessel, reddish-yellow fumes will immediately form around the wood, gradually filling the whole bottle. These fumes are

Fig. 95.

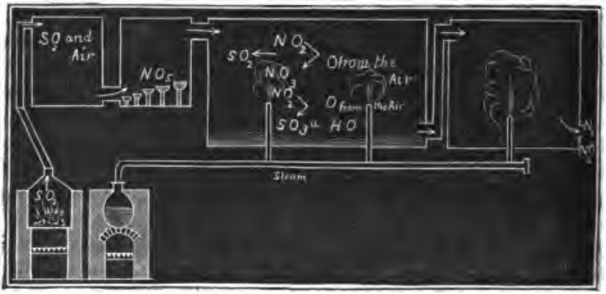
nitrous acid, and their evolution indicates that the sulphurous acid has withdrawn oxygen from the nitric acid, and has been oxidised and converted into sulphuric acid. After some time the bottle becomes clear again, because the vapour of the sulphuric acid formed sinks to the bottom, and dissolves in the water, and we can now again burn sulphur in the bottle. If we repeat this operation several times, we can soon prepare a few ounces of diluted sulphuric acid.

Experiment.—Add some drops of a solution of *muriate of baryta* (chloride of barium) to a portion of the acid liquid just obtained; a copious white precipitate is formed, which disappears neither by boiling, nor by the addition of water, nor by nitric acid. This precipitate is *sulphate of baryta*, a salt quite insoluble in water and acids. Add one drop of the diluted acid to a wine-glassful of water, and add to this a little more of the solution of baryta; even at this great dilution a perceptible cloudiness will be produced. A solution of chloride of barium, or of nitrate of baryta, is the most certain test for detecting sulphuric acid and sulphates.

172. *The manufacture of common sulphuric acid on a large scale* is conducted on the same principle as in the last experiment but one. The sulphur is burnt in an oven, from which a pipe leads into large leaden chambers. Vessels containing *nitric acid* are placed in one of the chambers, and some *water* is poured upon the floor. The *sulphurous acid* abstracts one atom of oxygen after another from the nitric acid, till this is converted into nitric oxide. The *nitric oxide* formed now acts in a very peculiar manner. It has been stated (§ 162) that this gas ($N\,O_2$), on coming into contact with the air, immediately abstracts from it one atom of oxygen, forming yellowish-red fumes of nitrous acid ($N\,O_3$); the same thing takes place in the leaden chambers, since *air* also flows into the chambers at the same time with the sulphurous acid. The nitrous acid readily gives up again this one atom of oxygen to bodies which have a desire for it. Such a body is sulphurous acid. Although it is too inert to take the oxygen directly from the air, it nevertheless receives the oxygen very willingly when it is presented to it by the nitrous acid. Thus the latter becomes again converted into nitric oxide, but the former into sulphuric acid. The nitric oxide again takes oxygen from the air, and gives

it up again to the sulphurous acid, and continues to perform this service as long as any oxygen is present. Finally, it is allowed to escape, together with the remaining nitrogen of the air. But it is essential, for the success of this process, that the *vapour of water* be also present; therefore steam is continually conducted into the chambers from a steam-boiler. This steam, together with the sulphuric acid formed, condenses on the cold walls, and collects on the floors of the chambers as an acid liquid. The annexed figure tends to elucidate this process.

Fig. 96.



By means of this remarkable property of nitric oxide, it has become possible, with an ounce of nitric acid, to obtain from 10 ounces of sulphur 30 ounces of concentrated common sulphuric acid. If the three atoms of oxygen released from the nitric acid were all the oxygen that operated, we should require more than 20 ounces of nitric acid to prepare 30 ounces of sulphuric acid. There are now some laboratories for the manufacture of sulphuric acid, of such colossal size, that they are able to deliver daily several hundredweights of prepared acid. The diluted acid formed in the leaden chambers requires still to be evaporated down nearly one-half, in order to convert it into common *concentrated sulphuric acid.* This evaporation is commenced in leaden vessels, and finished in glass or platinum retorts. The water, being more volatile, escapes, and carries off with it only a small portion of the acid. When the specific gravity of the latter becomes 1.84—that is, when 1840 grains of the acid can be put into a vessel capable of containing just 1000 grains of water, the evaporation is stopped, and the acid is transferred to large glass bottles, or carboys. One pound of common sulphuric acid contains three ounces of water, and consists of one atom of acid and one atom of water; but this atom of water is retained so firmly that it cannot be expelled by any heat. This acid is therefore called, also, *hydrated sulphuric acid*, $= H\ O, S\ O_3$. It is known in commerce as oil of vitriol.

173. *Experiments with Sulphuric Acid.*

Experiment a.—Let some sulphuric acid remain in an open flask exposed to the air; it will increase every day in weight, *for it very eagerly attracts water from the air.* After standing for some months in a damp place it will become two or three times heavier than before. This explains why the lucifer-match bottles formerly in use became so readily saturated with water. Some substances impregnated with water, especially gases, are dried by means of sulphuric acid.

Experiment b.—A piece of wood introduced into sulphuric acid becomes black, and is charred just as when it is exposed to the flame of a candle. The sulphuric acid seizes upon its hydrogen and oxygen, which combine to form water, and the carbon is left behind. Wood may be charred in this way, in order to protect it from decay in moist situations. In the refining of lamp-oil, the mucilage of the oil is charred by sulphuric acid. *Sulphuric acid chars and destroys most vegetable and animal substances.*

Experiment c.—Pour a drop of oil of vitriol upon paper; decomposition takes place slowly, but it will take place instantaneously if some drops of water are added, because *water and sulphuric acid unite together with the evolution of strong heat.* For this reason, when sulphuric acid comes in contact with the skin, it should first be wiped off with dry paper or cloth, and then be immediately washed with a great quantity of water. If 50 measures of sulphuric acid are mixed with 50 measures of water, we do not obtain 100 measures, but only 97 measures, of liquid; consequently, a contraction or condensation has occurred, which condensation is always attended with the liberation of heat.

Experiment d.—Pulverise a small quantity of *indigo*, and form a thin paste of it with *fuming sulphuric acid.* After a few days add to it some water, and you obtain a deep blue liquid—solution of indigo. With this solution wool may be dyed of a fine blue colour (Saxon-blue). Common sulphuric acid dissolves indigo only imperfectly. Indigo, although a vegetable substance, is not carbonised by sulphuric acid, thus forming an exception to the general rule.

Experiment e.—If, during the winter season, you place one vessel containing fuming sulphuric acid, and another containing the common acid, in a cold place, the stronger oil of vitriol will freeze at 32° F. (0° C.), but the weaker common sulphuric acid will not freeze until the temperature falls to —29° F. (—34° C.)

Experiment f.—Dissolve half an ounce of the soda of the shops in warm water, and neutralise it with dilute sulphuric acid; evaporate until a film forms upon the surface, when, on cooling, prismatic crystals will be deposited; they possess a bitter saline taste, and are *easily soluble* in water. The common soda of the shops is carbonate of soda ($Na\,O, C\,O_2$); the carbonic acid is displaced by the stronger sulphuric acid, and escapes with effervescence, but sulphate of soda (Glauber's salts) remains behind in the liquid. Almost all spring-water contains small quantities of soluble sulphates; the insoluble or almost insoluble sulphates are often accumulated in enormous masses in nature, forming whole mountains, as, for instance, gypsum.

Experiment g.—Mix to a thin paste half an ounce of litharge with water, and add gradually a quarter of an ounce of common sulphuric acid; after a while a white insoluble body is formed. The acid unites with the oxide, forming sulphate of the oxide of lead; this is *an insoluble salt.*

Experiment h.—To half an ounce of copper scales, such as fall off at the coppersmiths', add two ounces of water, and then gradually two-thirds of an ounce of sulphuric acid, and put it in a warm place; you obtain a blue solution, from which afterwards blue oblique, rhomboidal crystals will be deposited. The edges of these crystals are usually obtuse, giving to the narrow sides a roof-like appearance. Copper scales consist of oxide of copper; and they combine with the acid, forming sulphate of oxide of copper (blue vitriol), a *soluble* salt. By the designation *vitriol* is always to be understood a sulphate of a metallic oxide. Copper or iron vessels are cleaned more rapidly and made brighter by water to which some sulphuric acid has been added, than by simple water alone, because the oxide, which tarnished the vessels, is dissolved by the acid.

Experiment i.—Put a small iron nail into a test-tube, and drench it with twenty drops of common sulphuric acid; it is not acted upon. But if you add a little water, about four or five times more than the acid, a brisk effervescence will ensue, and the iron will be dissolved. The strong acid may be heated to boiling in iron vessels without acting upon them, which is by no means the case with the diluted acid. It has already been stated (§ 89) that, in this experiment, hydrogen escapes, and sulphate of iron remains in solution. The iron becomes protoxide of iron, not through the oxygen of the acid, but through that of the water. Zinc and tin comport themselves in the same manner. Consequently, the *diluted acid* must be employed for dissolving such metals. But there are also metals which dissolve only in the stronger acid, for instance, copper, silver, &c.; this will be treated of more fully under sulphurous acid.

Experiment k.—If a meadow or field be irrigated with one pound of sulphuric acid, diluted with 1000 pounds of water, the soil will be rendered more fertile and productive. The reason is, that the sulphuric acid decomposes and renders soluble several kinds of earth; whereby soluble sulphates are formed which are absorbed by the plants, and assist their growth. Sulphuric acid, if only 100 times diluted, has the contrary effect, and may be used for destroying grass on gravel paths.

2.) *Sulphurous Acid* ($S\ O_2$).

174. This suffocating gas is formed, not only by the combustion of sulphur, but may also be prepared from sulphuric acid, by depriving this acid of one atom of oxygen.

Experiment.—Put into a flask (see Fig. 93) half an ounce of copper turnings, and two ounces of common sulphuric acid, and conduct the gas ($S\ O_2$), as it escapes, into a four-ounce bottle filled with water (for the precaution to be taken, see § 92); the gas will be absorbed by the water in great quantities, and will impart to it an acid taste and a suffocating odour, like that of burning sulphur. One measure of water dissolves about forty measures of sulphurous acid.

When the gas ceases to be absorbed by the water, substitute a bottle filled with a solution of carbonate of soda; this likewise absorbs the gas, and forms with it sulphite of soda, while the carbonic acid of the carbonate of soda escapes. After sufficient evaporation, the salt formed will shoot out into white crystals, now known in commerce by the name of antichlorine; it is able to bind the chlorine that may happen to remain in the material during the bleaching, and to render it harmless. Sulphite of soda has not the odour of sulphurous acid, unless when diluted sulphuric acid is poured upon it, which combines with the soda, and expels the feebler sulphurous acid.

Experiment.—Infuse logwood shavings in warm water, and pour into the dark liquid thus obtained some sulphurous acid water; a decolorisation of the liquid will immediately take place. Sulphurous acid *bleaches vegetable colours.* Straw, wool, silk, and catgut—indeed animal substances especially—are very commonly bleached with sulphurous acid. The most simple method is to moisten them with water, and suspend them in a chamber or in a box, on the floor of which is placed a vessel containing burning sulphur. The bleaching power of this acid is beautifully exemplified on holding a rose or a peony over a burning stick of sulphur. If some drops of strong sulphuric acid be added to the bleached infusion of logwood, its original dark red colour *will again be restored;* consequently the colouring matter has not been completely destroyed by the sulphurous acid, as it would have been by chlorine; but it has only combined with the acid, forming a colourless compound, which may be broken up again by a stronger acid.

Experiment.—If a lighted taper is held over burning sulphur, or introduced into a vessel of sulphurous acid gas, it will be *extinguished,* as it was by nitrogen or by carbonic acid. The continuation of the combustion is prevented, because the gas contains no free oxygen. It may be now readily explained how chimneys on fire are extinguished by scattering sulphur on the coals beneath; the sulphurous acid gas ascends in the chimney, and expels the atmospheric air present in it; the glowing soot is thereby deprived of the free oxygen, and is extinguished.

175. It now remains to inquire, what has become of the

copper and the sulphuric acid, from which the sulphurous acid was prepared.

Experiment.—When the residue in the flask has become cold, add water to it, and heat it gently to boiling, until the whole saline mass is dissolved. The solution is dark and turbid, because fine particles of charcoal, contained in almost every metal, are floating about in it; but after filtering, it is of a beautiful blue colour, and transparent. If allowed to cool slowly, blue crystals of sulphate of the oxide of copper (blue vitriol), of considerable size, are formed; it is identical with the salt obtained by the solution of the copper scales in sulphuric acid. The oxygen by which the copper was oxidised proceeded from the sulphuric acid, half of which gave up an atom of oxygen, and was thereby converted into sulphurous acid, but the other half combined with the oxide of copper just formed. If copper, like iron, could be oxidised by the oxygen of water, then one ounce of sulphuric acid, instead of two ounces, would have sufficed for half an ounce of copper. Consequently, in preparing blue vitriol, it is more economical previously to convert the copper into oxide by heating it to redness in the air, and then dissolving it in sulphuric acid. Silver and mercury comport themselves also like copper. When they are to be dissolved in sulphuric acid, *concentrated* acid must be used.

Volatile.

Non-volatile.

When larger quantities of sulphurous acid are required, it is usually prepared by heating sulphuric acid with charcoal. The charcoal likewise abstracts one atom of oxygen from the sulphuric acid, and becomes converted into carbonic oxide, which escapes in company with the sulphurous acid.

Volatile.

Volatile.

The following proportions, in weight, of sulphur and oxygen, always exist in the two combinations just considered:

16 oz. of sulphur and 24 oz. of oxygen, or 1 at. S and 3 at. O, form SO_3.
16 " " " 16 " " " 1 " S and 2 " O, " SO_2.

Sulphur forms with oxygen several other acid combinations, as hyposulphuric acid, trithionic acid, hyposulphurous acid, tetrathionic, and pentathionic acids; but these, as less important, will not be treated of here.

PHOSPHORUS AND OXYGEN.

1.) *Phosphoric Acid* (PO_5).

176. When phosphorus burns with a flame in oxygen, or in the air, a white acid vapour, called *phosphoric acid* (§ 65), is formed; 32 grains of phosphorus are thereby always combined with 40 grains of oxygen, or 1 atom of phosphorus with 5 atoms of oxygen; this acid, consequently, has the formula PO_5. If phosphorus is burned under a dry bell-glass, this vapour will be deposited as a white powder (anhydrous phosphoric acid), which deliquesces in the air, but dissolves in water, for phosphoric acid is hygroscopic, and easily soluble in water. Such a solution may also be obtained by boiling phosphorus for a long time with nitric acid. In the preparation of it by combustion, the air furnishes the oxygen; on boiling with nitric acid, the acid itself supplies it. We find phosphoric acid, however, already existing in many substances, especially in the *bones* of the mammalia and birds, from which it may be prepared.

Experiment.—Weigh a *bone*, put it in a furnace-fire, and let it remain there for some hours; it first becomes black and then again white. Now take it from the fire and again weigh it; it has lost about one-third of its weight. That which was lost in burning was gelatine, which was first charred by the heat and then burnt, that is, converted into gas, which volatilised; the remaining non-volatile parts are called *bone-ashes*, and consist principally of phosphate of lime. Reduce this to a fine powder. Put two-thirds of an ounce of it into a flask, and add to it half an ounce of sulphuric acid and four ounces of water; let it stand for some days in a warm place, occasionally shaking it. Then pour the somewhat thick mass upon a cloth, and squeeze out the liquid. This no longer contains sulphuric acid, but phosphoric acid, with a little lime. The sulphuric acid remains on the cloth; it has combined with the lime, and expelled the phosphoric acid. The sulphate of lime (§ 164) is then washed with water and dried.

Sulphuric acid in the moist way is, as we see, stronger than phosphoric acid, but at a red heat the contrary is the case; if gypsum is heated to redness with phosphoric acid, the sulphuric acid will be driven off, so extraordinary are the changes which affinities experience at different temperatures. At a great heat, the least volatile acids are always the strongest; among these belongs phosphoric acid, since it does not volatilise until it attains a white heat. If this phosphoric acid is evaporated, we obtain it (still containing some lime), first as a sirupy liquid, and finally as a vitreous solid mass.

To detect phosphoric acid, add to a solution of it some drops of a solution of nitrate of silver and ammonia; a yellow precipitate is produced (phosphate of the oxide of silver). But if the acid had been previously ignited, the precipitate would have been white; consequently, the properties of phosphoric acid are partially changed by strong ignition. A more accurate test consists in adding to the liquid under examination a few drops of a solution of Epsom salts and ammonia; if phosphoric acid be present, a crystalline precipitate (§ 251) is formed.

The body of an adult man contains about
from 9 to 12 pounds of bones, containing
" 6 " 8 pounds of bone ashes, containing
" 5 " 7 pounds of phosphate of lime, containing
" 2¼ " 3 pounds of phosphoric acid, containing
" 1 " 1¾ pounds of phosphorus.

Phosphates are also contained in the blood, flesh, and other portions of the body. Whence does it obtain this phosphorus? Answer: from the meat and vegetables which it consumes. The phosphates occur in bread, in all kinds of grain, in leguminous and many other plants, particularly in their seeds. But how do the plants obtain these salts? By means of the soil. If arable land contained no such salts, no seeds could be produced. If we increase their quantity by mixing ground bones with the soil, we place the latter in a situation to produce a larger quantity of grain; consequently, bones furnish us with a powerful manure.

That the gelatine contained in them contributes also to the growth of plants, will be treated of hereafter.

2.) *Phosphorous Acid* ($P\,O_3$).

177. This acid, which contains for one atom of phosphorus only three atoms of oxygen, is formed principally when phosphorus is slowly burnt, that is, when without being heated it takes up oxygen from the air, as was shown in § 140.

3.) A combination of equal atoms of phosphorus and oxygen is called *hypophosphorous acid.*

4.) *Oxide of Phosphorus* ($P_2\,O$). The red substance formed during the imperfect combustion of phosphorus (§§ 142, 143) contains even less oxygen than hypophosphorous acid, and is called *oxide of phosphorus.*

In phosphoric acid ($P\,O_5$) 32 ounces of phosphorus are always combined with 40 ounces of oxygen, or 1 atom P with 5 atoms O; in phosphorous acid ($P\,O_3$), 32 ounces of phosphorus are always combined with 24 ounces of oxygen, or 1 atom P with 3 atoms O.

CHLORINE AND OXYGEN.

178. *Chlorine* has but a feeble affinity for oxygen, and can only be combined with it in an indirect way, and with the assistance of strong bases, which immediately unite with the acids produced, forming salts.

1.) *Hypochlorous acid* is a combination of two measures or one atom of chlorine with one atom of oxygen ($Cl\,O$), and it is characterised by its power of destroying all vegetable colours. It is resolved with great ease into free chlorine and oxygen. It is the *bleaching* principle of the well-known *chloride of lime.*

2.) *Chloric acid* consists of one atom of chlorine and five atoms of oxygen; thus its formula is $Cl\,O_5$. As it is so rich in oxygen, and releases it very readily when heated, its salts are frequently employed for obtaining oxygen, or for combining other substances with oxygen (oxidising them). The salt of this kind most commonly employed is the chlorate of potassa, which was used in some of the earlier experiments.

3.) *Perchloric acid* is a combination of one atom of chlorine and seven atoms of oxygen.

Bromine and *iodine* comport themselves like chlorine, and combine with oxygen, forming acids, which are easily decomposed. Fluorine does not unite at all with oxygen.

CYANOGEN AND OXYGEN.

179. *Cyanogen*, although composed of two elements (carbon and nitrogen), comports itself, nevertheless, exactly like a simple body, and, moreover, like a halogen, and forms several acids with oxygen. Two of these are of great interest in a scientific point of view, because they have exactly the same constitution, but entirely different properties. They consist of equal atoms of cyanogen and oxygen. One of them is called *fulminic acid* ($Cy_2\ O_2$), and exists united with the oxide of mercury in fulminating mercury, and with the oxide of silver in fulminating silver. The well-known percussion-caps afford a familiar example of the violence with which these salts explode on being rubbed or struck by some hard body. One of these caps contains only one-third of a grain of fulminating mercury. The fulminic acid separates, on exploding, into two gases—nitrogen and carbonic oxide—which suddenly occupy a space several thousand times greater than before. The second acid is called *cyanic acid* ($Cy\ O$); it likewise decomposes very readily, but without explosion or danger.

Bodies which contain just the *same* constituents, and in exactly the same quantity, but at the same time are quite *dissimilar* in their properties, are called *isomeric* (from ἴσος, *equal*, and μέρος, *part*), or similarly constituted bodies.

BORON AND OXYGEN.

Boracic Acid, $Bo\ O_3$.

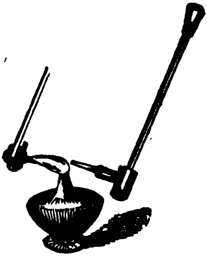
180. *Experiment.*—Dissolve in a porcelain dish half an ounce of borax in an ounce and a half of boiling water, and add muriatic acid by drops to the solution, until the liquid gives a strong acid reaction. On gradually cooling it, the boracic acid will separate in scaly plates, which are purified by being again dissolved and recrystallised. Boracic acid is combined in borax with a base, soda. The stronger muriatic acid seizes upon this soda, and forms with it muriate of soda (or chloride of sodium and water), which remains dissolved, while the less so-

Fig. 97.

luble boracic acid separates from the liquid in crystals. There are some places in Italy where hot watery vapours containing boracic acid issue from the earth. Large quantities of this acid are now obtained from these vapours, by conducting them into basins of water, where they condense with the boracic acid.

Experiment.—Take a piece of thin platinum wire, about two and a half inches long, and bend one end of it into a hook. Moisten this part with the tongue, and dip it into boracic acid, so that a small portion of it may remain adhering to the platinum. Now blow through a blow-pipe into the flame of a spirit-lamp, and hold the boracic acid at the point of the horizontal flame. It will first melt and swell in its water of crystallisation into a spongy mass; but, by continuous blowing, it will be converted into a transparent *glass bead*. Boracic acid does *not volatilise* on ignition. If you moisten the glass bead, and apply to it either powdered chalk, litharge, or iron-rust, and again heat it to melting, these substances will unite most intimately with the boracic acid, and be dissolved by it, and likewise vitrified. Most of the combinations of boracic acids with bases become *vitreous* when heated; that is, they melt together, forming sometimes a white, and sometimes a coloured glass.

Fig. 98.



181. The *blow-pipe* is an excellent instrument for volatilising, heating to redness, melting, oxidising, or reducing substances, on a small scale. Twofold combustion takes place in the blow-pipe flame—in the interior by means of the air which is blown into it, and externally by means of the atmospheric air. By this means two cones of light are formed —a smaller *inner* cone, of a blue colour, and a larger *outer* cone, of a yellowish appearance. The former is called the *reducing flame*, the latter the *oxidising flame*. If you wish to take oxygen from a body—for instance, from an oxide—hold it at the point of the blue inner flame, where it meets with soot or carbon, which combines with the oxygen of the oxide, forming carbonic acid. But if, on the other hand, a body is to be oxidised, then it is held at the point of the outer flame, where the oxygen of the air can have free access to it. In

order to acquire a practical knowledge of the blow-pipe, first try to convert a piece of lead, placed upon charcoal, into an oxide, by exposing it to the outer flame; and afterwards to restore this oxide to its original metallic state, by exposing it to the inner flame, in order to reduce it. The habit must, moreover, be acquired of breathing through the nose while blowing, and to do this the cheeks must be kept constantly distended. When this habit is acquired, the chest is no longer strained by blowing, and an uninterrupted stream of air may be kept up for a long time.

182. *Experiment.*—If you mix some boracic acid in a mortar with alcohol, and kindle the latter, it will burn with a *green flame.* In this way boracic acid may easily be detected. Some of the acid, which is not alone volatilised by heat, as we have shown in a previous experiment, is volatilised with the alcohol. Other bodies also exhibit a similar inconsistency. When heated by themselves, they are completely non-volatile, but they volatilise, and frequently at very low temperatures, *when mixed with another body which is very volatile.* Thus, in the present instance, the alcohol is the occasion of the volatilisation of the boracic acid. Hot steam will also render large quantities of non-volatile silicic acid volatile, and carry it off with itself. Common salt is constantly taken up by the vapours which rise from the ocean into the air. It is again precipitated with the rain, and in this manner is diffused over the whole earth.

Boracic, like phosphoric acid, is, in the moist condition, a very weak acid; but at a red heat it is one of the strongest acids.

SILICON AND OXYGEN.

Silicic Acid, or Silica ($Si\ O_3$).

183. That which is commonly called flint is called in chemistry *silicic acid.* We find it tolerably pure in quartz, sandstone, pumice-stone, and flint, and in rock crystal often beautifully crystallised in six-sided prisms, or six-sided pyramids, and so transparent, that ornamental stones, the so-called Bohemian diamonds, are made from it. Red cornelian, violet amethyst, green chrysoprase, the variegated agate and jasper, opal and chalcedony,—these well-known precious stones consist, likewise, of silica;

Fig. 99.

their colours are chiefly owing to the presence of metallic oxide. Common sand is silica, rendered yellow or brown coloured by hydrated oxide of iron (rust). In its natural state, silica is so hard as to produce sparks with steel, and is quite insoluble in water and acids, except hydrofluoric acid. It may, perhaps, seem astonishing to some that such bodies as our common sand, or flint, should be included among the acids. The reason is, that silica, just like other acids, combines with bases, and forms salts.

Experiment.—Boil in a porcelain vessel one drachm of finely-ground sand and two drachms of caustic potassa, with one ounce of water, for some hours, supplying the water, occasionally, as it evaporates; then let the mixture stand in a closed vessel, for the impurities to settle. Part of the sand dissolves in the solution of potassa, and forms with it a thickish opalescent mass. If you add muriatic acid to this solution, a thick gelatinous precipitate of silicic acid will be formed. If, on the contrary, you previously dilute the liquid with from ten to twelve times its quantity of water, and then remove the potassa by muriatic acid, the liquid will remain clear, and the silicic acid remain dissolved in the water. But this solubility is destroyed as soon as the solution is evaporated to dryness, and the silicic acid then forms a white powder, which is no longer soluble in water. Thus, as is evident, silicic acid exists in two entirely different isomeric modifications, one *insoluble*, as occurring in siliceous stones and rocks; and another *soluble*, as found in plants and water.

Almost all our springs, as well as our plants, contain small quantities of silicic acid. If we evaporate spring-water, we find silica in the insoluble residue; and if we burn a plant, we obtain it in the ashes. Grasses, and the different kinds of grain, are particularly rich in silica, and for this reason they have been called *siliceous plants*. Silica is to these plants what bones are to men,—the substance to which the stalk owes its firmness and stiffness. If the soil is deficient in soluble silica (or if there is not enough potassa, which renders the silica soluble), these properties will be wanting in the stalk, and it will bend. The horse-tail plant (Equisetum) contains so much silica that it may be used for polishing wood. Silicic acid is found even in the animal kingdom, particularly in the class of Infusoria, which are only visible under the microscope; the shells of many Infusoria are composed of silicic acid.

The combination of silicic acid with bases may be effected more completely by *fusion*. Most of the silicates thus obtained are *amorphous*, and are known by the name glass. Silicic acid has in this respect the greatest resemblance to boracic acid, and it also resembles it in being an extremely feeble acid in its moist state; but when heated, on account of its non-volatility, it surpasses all other acids in strength. Alone, silicic acid can only be melted by the heat of the oxyhydrogen blow-pipe.

RETROSPECT OF THE OXYGEN ACIDS.

1. Most of the combinations of the metalloids, or non-metallic elements, with oxygen, are *acids* (acid oxides).

2. Most of the combinations of the metals with oxygen are *bases* (basic oxides).

3. The acids *redden* blue test-paper, the bases colour the red paper *blue* (when they are soluble).

4. The acids have an *acid* taste, and the bases an *alkaline* taste (when they are soluble).

5. When acids and bases combine together, the acid as well as the basic properties are destroyed (neutralisation), and new compounds are formed, *salts;* these have a brackish taste if soluble in water, but are tasteless if insoluble in water.

6. The principal characteristic of the acids is, *that they combine with bases, forming salts;* therefore we class all bodies which do this among the acids, even if they do not possess an acid taste or reaction. The same rule applies conversely to the bases.

7. Most of the acids, in the state in which they are commonly obtained and employed, are chemically combined with a fixed quantity of *water* (hydrates). Many acids cannot exist without water (water of constitution). By adding more water, we obtain the *diluted acid.*

8. One and the same element often forms several acids, with different, but always fixed, quantities of oxygen.

9. The acids have different affinities for bases; some have a greater affinity—for example, sulphuric acid; others a less,

as carbonic acid; the former is called a *strong*, the latter a *feeble* acid. Feeble acids may be expelled from their combinations by the stronger ones.

10. The non-volatile acids are, when heated (in their dry condition), mostly *stronger*, but at ordinary temperatures (in the moist condition) *weaker*, than the volatile acids. The strength of the affinity consequently varies according to the temperature.

11. The acids just considered are called in a strict sense *oxygen acids*, because they contain oxygen, and owe to it their acid properties.

12. The combinations of oxygen acids with bases are called in a strict sense *oxy-salts*.

SECOND GROUP: HYDRACIDS, OR COMBINATIONS OF THE HALOGENS WITH HYDROGEN.

184. As oxygen combines with the metalloids, forming acids, so also hydrogen can convert some of them into acids. *The five halogens—chlorine, bromine, iodine, fluorine, and cyanogen—are acidified by hydrogen.* Oxygen, as has been shown, is able to form several acids with one and the same metalloid; for instance, with sulphur it forms sulphuric and sulphurous acids; with nitrogen, nitric and nitrous acids, &c.; but hydrogen produces, with each of the above-named halogens, only a *single* acid or combination.

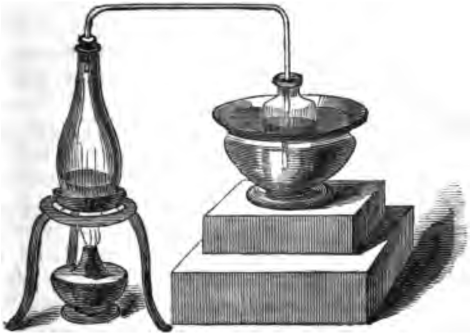
CHLORINE AND HYDROGEN, MURIATIC ACID ($H\,Cl$).

185. *Experiment.*—Put into a porcelain capsule a few grains of common salt, and pour a little sulphuric acid upon them; there escapes, with effervescence, a gas, which has a pungent odour, an acid taste, and reddens moistened blue test-paper; this gas is *muriatic acid*, or *hydrochloric acid.* If you pour some ammonia upon a shaving, and wave the latter to and fro over the capsule, a thick white smoke is formed; and the odour of both the muriatic, and also the pungent fumes of the ammonia, vanish. The acid fumes are neutralised by the volatile base contained in the ammonia; there is formed an odourless salt (chloride of ammonium), and in such a minute state of subdivision, that it floats in the air. We can, in this way, easily determine whether the air contains muriatic

acid, or, by reversing the experiment, whether it contains ammonia, and also deprive these gases of their suffocating and injurious properties, and remove them from the air.

Experiment.—Mix carefully in a flask a quarter of an ounce of water with three-quarters of an ounce of sulphuric acid, and after the mixture has become cold, add to it half an ounce of common salt. Adapt to the neck of the flask a cork provided with a glass tube, the long limb of which passes into a phial, containing one ounce of water. If you heat the flask in a sand-bath, the muriatic acid escapes, but more quietly than in the former experiment, because the sulphuric acid has been somewhat diluted. The tube must only just dip into the water; for should it reach to the bottom of the phial, the whole liquid might suddenly flow back into the flask, if the heat should chance to slacken, as it might, for instance, from the flickering of the spirit-lamp by an accidental current of air. The muriatic acid is so eagerly absorbed by the water, that, when the evolution of the gas diminishes, a vacuum is formed in the tube and flask; the exterior air then presses more strongly upon the water and forces it up. (§ 92.) When a gaseous body condenses into a liquid, it no longer requires the latent heat by which it became gas or vapour, and therefore this heat is set free. From this it follows that the water in which the muriatic acid condenses or dissolves must soon become warm. But

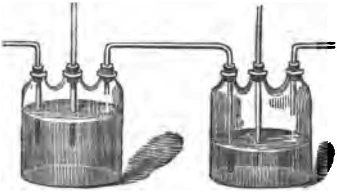
Fig. 100.



warm water takes up much less gas than cold; accordingly, in order to obtain a concentrated solution of muriatic acid gas, we must place the phial in a basin of cold water. When the liquid in the receiver has sufficiently increased, one of the blocks must be withdrawn from beneath, so as to keep the end of the tube near the surface of the liquid. The solution thus obtained has an intensely acid taste and reaction; it is called *hydrochloric acid*, but is commonly known under the name of *muriatic acid*. One measure of water absorbes more than four hundred measures of muriatic acid gas; the strong muriatic acid thus obtained fumes in the air, because a part of the gas escapes. If you heat it to boiling, then half of it escapes, and an acid only half as strong remains behind; but this is always somewhat *heavier* than water.

The muriatic acid of commerce is commonly yellow, and contaminated with sulphurous acid, sulphuric acid, chlorine, iron, and sometimes even with arsenic. It is also manufactured from common salt and sulphuric acid; but, instead of glass vessels, large iron cylinders are employed, capable of containing some hundred-weights of common salt. The gas is conducted into several bottles or jars, connected with each other, and which are filled with water. When the water in the first vessel becomes saturated with the hydrochloric acid gas, the gas passes over into the second, then into the third vessel, and so on, saturating each successively. This is a very convenient method of conducting gases through liquids. Such vessels, which are commonly provided with two or three necks, are called *Woulfe's bottles*. The upright tube in the middle neck serves as a safety tube, that is, it prevents the liquid from being forced back; if a vacuum is formed in one of the bottles, the air enters through this tube.

Fig. 101.



Common salt consists of chlorine and sodium; if water is added to it, the chlorine will abstract from it hydrogen, and the sodium oxygen, and muriate of soda is formed. This is

Volatile.

Non-volatile.

decomposed by the more powerful sulphuric acid, which combines with the base, and expels the hydrochloric acid. The sulphate of soda (Glauber salts) remains behind as a white salt, and is used in the manufacture of that important article, carbonate of soda.

The constituents of muriatic acid gas are equal atoms of chlorine and hydrogen, and it is represented by the symbol $H\ Cl$.

If you fill a glass vessel half with chlorine and half with hydrogen, and put it in a dark place, no union ensues; but it takes place instantaneously when the vessel is exposed to the direct rays of the sun. The union is accompanied by a violent detonation, which often breaks the vessel, so that it is not advisable to perform this experiment. But it proves that light also compels some substances to combine chemically with each other.

186. *Experiments with Muriatic Acid.*

Experiment a.—Put some iron nails into a phial, and pour upon them some muriatic acid; brisk effervescence will ensue. When this has continued some minutes, hold a burning taper over the mouth of the phial; the gas which escapes takes fire; it is hydrogen. The muriatic acid is decomposed, and its second constituent, chlorine, combines with the iron. The iron disappears, and it dissolves; that is, it combines with the chlorine, forming a soluble compound. When the effervescence has ceased, heat the phial by placing it in hot water, and afterwards pour its contents upon a filter of white blotting-paper. Put the liquid which passes through (*the filtrate*) in a cool place; a salt is deposited from it in greenish crystals, called *protochloride of iron* ($Fe\ Cl$), that is, iron united with but little chlorine.

Many other metals are also dissolved, like iron, by muriatic acid, and converted into salts.

Experiment b.—Pour some muriatic acid upon iron-rust that has been put into a test-tube; it dissolves, but without evolution of gas. In this case, the hydrogen of the muriatic acid meets with a body with which it can combine, namely, the oxygen of the oxide of iron; and it does combine with it, forming water. The yellowish-brown solution, which it is difficult to crystallise, yields, upon evaporation, a brown mass called *sesquichloride of iron* ($Fe_2\,Cl_3$). This salt contains one half more chlorine than the former. Muriatic acid is very often used for dissolving metallic oxides.

Experiment c.—Dissolve some crystals of the protochloride of iron, obtained according to experiment *a*, in a little water, and then add some chlorine water; the greenish colour is converted into a yellow colour, and the solution yields, on evaporation, brown *sesquichloride of iron*. The chlorine combines with the protochloride of iron, and converts it into sesquichloride of iron.

Experiment d.—Dissolve some carbonate of soda in water; the solution turns red test-paper blue; it has a basic reaction. Drop carefully into the solution some muriatic acid, until neither the red nor the blue paper is affected by it. Thus muriatic acid, just like an oxygen acid, has the power of neutralising bases. If you put the liquid in a warm place a salt will be deposited in small cubes; you readily perceive, both by the shape of the crystals and by the taste, that it is common salt. Here also the oxygen of the base has combined with the hydrogen of the muriatic acid, forming water, but the chlorine with the sodium, forming common salt. The carbonic acid of the carbonate of soda escapes with effervescence.

Experiment e.—If you drop into a test-tube some muriatic acid, and then a few drops of a solution of nitrate of silver (lunar caustic), a white cloudiness is formed, which does not happen in pure water. This cloudiness proceeds from the chloride of silver, which is insoluble in water. Nitrate of silver is the most accurate test for muriatic acid and its salts.

If muriatic acid is diluted with from 800 to 900 parts of water, and is poured upon land, it exhibits a fertilising power, like that of sulphuric acid. (§ 173.)

187. *Haloid Salts.*—Like chlorine, the other salt producers, or halogens, also combine with metals forming salts; these salts are called *haloid salts*. As has been shown, they may be prepared—

1.) By uniting a halogen with a metal. (§ 156.)
2.) By uniting a halogen with a metallic oxide. (§ 152.)
3.) By the solution of a metal in a hydrogen acid. (§ 186.)

4.) By the solution of a metallic oxide in a hydrogen acid. (§ 186.)

If the two last-mentioned instances be attentively considered, it may, perhaps, appear surprising why it was not assumed that muriatic acid combined with the base without further decomposition, just as it was assumed with regard to sulphuric acid, and the other oxygen acids. This cannot generally happen, because many of the haloid salts, when they are quite dry, contain neither oxygen nor hydrogen. Completely dried common salt, for example, contains no hydrochloric acid, but chlorine—no oxide of sodium, but sodium; as has been ascertained by the most accurate experiments. But if the haloid salts contain water, or are dissolved in water, then they may certainly be regarded as consisting of a base and a hydrogen acid, for it amounts to the same thing, whether the hydrogen be considered as existing in the water or in the hydrogen acid, the oxygen in the water or in the metallic oxide. A solution of common salt may accordingly be regarded either as chloride of sodium and water, or as muriate of soda. ($Na\,Cl + H\,O$ is the same as $Na\,O, H\,Cl$.)

Formerly the combinations of chlorine with the metals were universally called *muriates*. The names, muriate of lime, muriate of baryta, muriate of oxide of iron, &c., have therefore the same signification as chloride of calcium, chloride of barium, chloride of iron, &c. When chlorine combines with a metal in several proportions, the combination with less chlorine is called protochloride, that with more chlorine, perchloride, and that with still more chlorine, perchloride. (§ 154.) If water is contained in them, or if they are dissolved in it, the protochlorides may be regarded also as *protomuriates*, and the perchlorides as *permuriates*; for example:

Protochloride of iron and water is the same as the protomuriate of the protoxide of iron:

$$(Fe\,Cl + H\,O = Fe\,O, H\,Cl.)$$

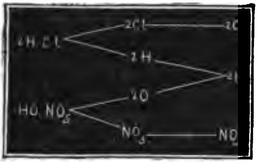
Perchloride of iron and water is the same as the muriate of the peroxide of iron:

$$(Fe_2\,Cl_3 + 3\,H\,O = Fe_2\,O_3 + 3\,H\,Cl.)$$

AQUA REGIA, OR NITRO-MURIATIC ACID ($2\,H\,Cl + N\,O_5$).

188. *Experiment.*—Put into a glass one drachm of nitric acid, and into another two drachms of pure muriatic acid,

and add to each some genuine gold-leaf; it will not be dissolved. But if both liquids are mixed together, the gold very soon disappears, because it is dissolved. Gold is deemed the king of metals, hence the name *aqua regia*. On evaporating this solution, a yellow salt remains behind, which consists of gold and chlorine. As the muriatic acid did not voluntarily give up its chlorine to the gold, it is highly probable that it was compelled to do so by the nitric acid. This process may be easily explained, if we refer to the preparation of chlorine from muriatic acid and the black oxide of manganese. The nitric acid acts upon the muriatic acid just like the manganese; it contains, like the latter, much oxygen, and parts with it very readily. This happens also in the present case, and the liberated oxygen abstracts from the muriatic acid its hydrogen, to form water. Consequently the chlorine is set free, which, being a simple and strong chemical body, immediately unites with the gold, which is likewise a simple body. The nitric acid loses thereby two atoms of its oxygen, and is converted into nitrous acid, which escapes in yellowish fumes.



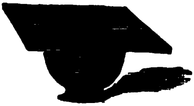
Aqua regia is employed for dissolving gold and platinum, neither of which metals is attacked by other acids.

BROMINE, IODINE, AND FLUORINE, + HYDROGEN.

189. *Hydrobromic and Hydriodic Acids.*—Both of these acids closely resemble muriatic acid. Their combinations with metals are called protobromides, perbromides, protiodides, and periodides, &c., of the metals. They occur in nature accompanying common salt, consequently in sea-water and marine plants, in salt springs, &c., but only in minute quantities.

190. *Hydrofluoric Acid.*—*Experiment.*—Rub to a powder a piece of fluor-spar, of the size of a hazel-nut, and put it into a small mortar, which has been previously rubbed with oiled paper; then pour sulphuric acid upon it till a thin paste is formed. Cover the mortar with a piece of window-glass, which has received a coating of wax, and from some parts of which the wax has been removed by scratching with a

Fig. 102.



needle, or other pointed instrument. After the lapse of some hours remove the wax by melting it, and then, rubbing it off with oil of turpentine, those parts of the glass left bare will be found to be *corroded.*

Fluor-spar consists of fluorine and calcium, and is decomposed by sulphuric acid, in the same manner as common salt was; hydrofluoric acid is formed and escapes in vapour. This acid has the property of *dissolving silica;* therefore it withdraws the latter from the glass, where it is not protected by the wax, and the glass consequently becomes rough and opaque. In this manner drawings are often etched on glass. By conducting the fumes into water, liquid hydrofluoric acid is obtained, which may likewise be employed for etching on glass. Lead or platinum vessels must be used in the preparation of it, on account of its property of corroding glass and porcelain. We also find fluoride of calcium, in small quantities, in the bones and teeth of the mammalia.

CYANOGEN AND HYDROGEN, HYDROCYANIC ACID (H Cy).

191. The great similarity which *Cyanogen*, composed of carbon and nitrogen, has to the halogens, is also manifested by its combining with hydrogen, forming an acid. This combination is the notorious *prussic* or hydrocyanic acid, a few drops of which are sufficient to kill instantaneously a small animal. As muriatic acid is obtained from chlorides by sulphuric acid, so prussic acid is also obtained from the cyanides by means of sulphuric acid, and it is also gaseous, like muriatic acid. To obtain it in a liquid form, the gas is conducted into water, or alcohol, by which it is absorbed. It is colourless, like water, and it is easily recognised by its strong oppressive odour, which is very similar to that of bitter almonds. Such a dangerous article should only be prepared by experienced persons. Prussic acid is found also in small quantities in some seeds, particularly in bitter almonds, and in the kernels of stone fruits, as plums, apricots, &c.

Prussic acid combines with bases, forming water and metallic cyanides (protocyanides and percyanides). The most familiar of these are the yellow ferrocyanide of potassium (prussiate of potassa), and the blue ferrocyanide of iron (prussian blue).

RETROSPECT OF THE HYDROGEN ACIDS.

1. The haloids or halogens—chlorine, bromine, iodine,

fluorine, and cyanogen—form *acids*, not only with oxygen, but also with *hydrogen*.

2. The halogens have a greater preference for *hydrogen* than for oxygen; hence, when they have the choice, they always combine with the former.

3. Hydrogen unites with the halogens only in *one proportion;* consequently, each of them forms only one single hydrogen acid.

4. All the hydrogen acids have the same constitution; they always consist of *equal* atoms of a halogen and hydrogen.

5. The hydrogen acids combine with the metals, forming chlorides, bromides, &c., whilst their hydrogen escapes.

6. These combinations of the halogens with the metals possess exactly the properties of salts; for this reason they are called *haloid salts*.

7. The hydrogen acids combine with the bases or metallic oxides, forming haloid salts and water.

8. If water is present in the haloid salts, they may be regarded as combinations of the hydrogen acids with bases, or as hydrogen acid salts, just as the oxygen salts are regarded as combinations of oxygen acids with bases.

9. Many metals combine with the halogens in several, generally in two, proportions. When the halogen is in excess, they are called perchlorides, perbromides, &c.; but when deficient, they are called protochlorides, protobromides, &c. The former correspond with the peroxide salts, the latter with the protoxide salts.

RETROSPECT OF THE COMBINATIONS OF THE METALLOIDS WITH OXYGEN AND HYDROGEN.

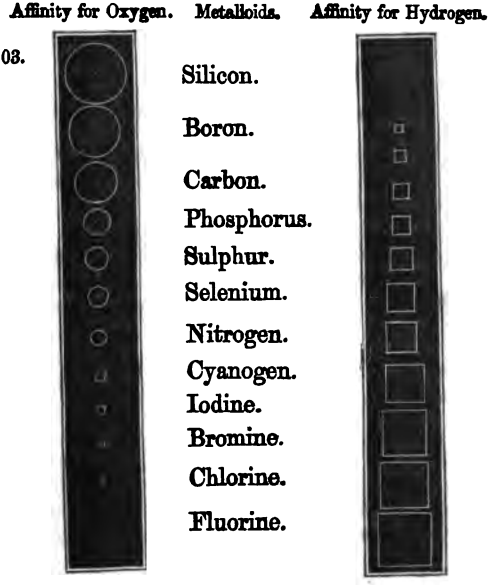
192. The combinations which *hydrogen* forms with the halogens have here been grouped together, because they have the greatest similarity to each other. These combinations possess the distinctive characters of strong acids. The other metalloids can also combine with hydrogen, but they do not form acids with it, sulphur alone being an exception, the combination of which with hydrogen certainly comports itself like an acid, though only as a very feeble one. (§ 132.) The contrary occurs with nitrogen; this forms with hydrogen a base, ammonia. The combinations of the other metalloids with hydrogen, some of which have already been treated of

under the separate metalloids, exhibit neither basic nor acid properties; they are, on this account, called neutral or indifferent bodies. Oxygen and hydrogen constitute the indifferent body, water; carbon and hydrogen, the indifferent illuminating and marsh gas; phosphorus and hydrogen form phosphuretted hydrogen, also an indifferent body.

The combinations which *oxygen* forms with the non-metallic elements, or metalloids, are, indeed, mostly acids, but we find among them some which possess an *indifferent* character; namely, nitrous and nitric oxides ($N\,O$ and $N\,O_2$), the oxide of phosphorus, and carbonic oxide gas ($C\,O$). As is obvious, the combinations with the *least* quantity of oxygen are those in which the acid properties are developed on the increase of the oxygen, and most strongly in those combinations which contain the greatest quantity of oxygen.

Since the combinations which the metalloids form, on the one hand with oxygen, and on the other with hydrogen, are among the most important and most interesting chemical bodies, an approximative idea of the strength of the affinities

Fig. 103.



which each of the metalloids possesses for these two elements may be shown by the annexed scheme. The size of the circles represents the affinity for oxygen, that of the squares the affinity for hydrogen. From this it is apparent that the partiality of the metalloids for hydrogen increases in proportion as it diminishes for oxygen, and the reverse.

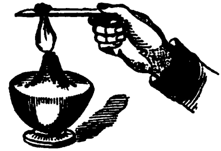
THIRD GROUP: ORGANIC ACIDS.

193. The oxygen and hydrogen acids are commonly called inorganic or mineral acids, because they are principally found in the mineral kingdom, or prepared artificially from minerals and earths. But there are, besides, many other acids, found either already existing in animals and plants (formic acid, citric acid), or which may be artificially produced from organic substances (lactic acid, acetic acid). Such acids are called *organic*, or vegetable and animal acids. They have the greatest similarity to the inorganic acids in their properties and combinations, but not in their constitution. Three of them only will be treated of at present as examples of this class of acids, one a volatile, and the other two non-volatile acids; the acids will be considered in the second and third parts of this work.

TARTARIC ACID (H O, $\bar{T}$).

194. Tartaric acid has very much the appearance of a salt; it crystallises in colourless oblique prisms, which are permanent in the air, and have a very acid taste.

Fig. 104.



Experiment.—Place a small crystal of tartaric acid upon a piece of platinum foil, and heat it over the flame of a spirit-lamp; it will first melt, then become brown, and finally black, and emit at the same time a peculiar empyreumatic odour. If, during the process of charring, you hold over the acid a dry, cold glass vessel, it will become lined with globules of water; consequently the acid contains oxygen and hydrogen. The dark residue resembles charcoal, but it is more certainly recognised as such by its burning completely at a higher heat. Accordingly, tartaric acid has, when heated, the greatest similarity to burning wood. In fact, it consists of the same elements, namely, carbon, hydrogen, and oxygen, but in different proportions. *All vegetable acids consist of* C, H, *and* O, *and are charred and consumed on being heated.* By these two characteristics the organic acids are essentially distinguished from the inorganic, which consist only of two elements, and which are neither charred nor consumed in the fire.

Experiment.—Pour a little warm water over some tartaric acid; it will dissolve therein, for it is *readily soluble* in water. If you dilute the solution with more water, and put it aside in a moderately warm place, slimy flakes will be deposited, and the acid taste will gradually be lost—it *putrefies.* In a similar manner, all organic acids, when they are diluted with water, decompose after a time.

Experiment.—Mix gradually a solution of tartaric acid with ammonia; there will be a period when the acid properties of the tartaric acid, and the basic ones of the ammonia will have disappeared. Accordingly, tartaric acid, just like other acids, can neutralise bases, and form with them salts. The tartrate of ammonia obtained is easily soluble.

Experiment.—Neutralise a solution of carbonate of potassa with a solution of tartaric acid; the carbonic acid escapes; the liquid, however, remains clear, because the neutral tartrate of potassa ($K\,O, \bar{T}$) formed is an easily soluble salt. But by adding yet more tartaric acid, the liquid becomes turbid, and deposits a quantity of small transparent crystals, which are difficultly soluble in water, have an acid taste, and contain twice as much acid as the neutral salt, besides, also, some water of crystallisation. These crystals are called acid tartrate of potassa, or bitartrate of potassa ($K\,O, 2\,\bar{T} + H\,O$); commonly, tartar, or when they are pulverised, cream of tartar. The salts of potassa may accordingly be used as a *test for tartaric acid.*

Tartaric acid is generally prepared from tartar or argol, which is obtained in large quantities from the wine countries, where it is deposited from wines in the casks, as a white or reddish crust. The potassa might be very easily removed from this salt by means of sulphuric acid; but then two soluble substances would be obtained, which could not well be separated from each other. For this reason, the potassa is first replaced by another base, namely, by lime, which forms with sulphuric acid an insoluble, or at least very difficultly soluble compound. By boiling tartar with water, and adding chalk to it, then *tartrate of lime* is obtained, as a white insoluble powder; if this, after being sufficiently washed, is put by for some time with water and sulphuric acid in a warm place (digested), the latter unites with the lime, and forms sulphate of lime, whilst the tartaric acid, being set free, dissolves in the water, and crystallises from the solution after evaporation.

The chemist is often obliged to resort to such circuitous means in order to separate two bodies from each other, both of which are equally soluble in water or in some other liquid.

Experiment.—If you heat the crystalline powder of tartar, obtained in the former experiment, on platinum foil, it will, like the tartaric acid, become black, and burns with an empyreumatic odour; but there will, however, finally remain a white powder, which has an alkaline taste, a basic reaction, and which, on the addition of an acid, will effervesce like carbonate of potassa. The acid burns up, but not the alkali; on the combustion of the acid, carbonic acid is formed, which combines with the potassa; consequently, carbonate of potassa is formed. All salts of the alkalies, or alkaline earths, with an organic acid, are in the same way decomposed by heat, and converted into carbonates.

195. We can decompose sulphuric acid into sulphur and oxygen; and from sulphur and oxygen we can again reproduce sulphuric acid. Not so, however, with tartaric acid; we may succeed in demolishing it, but it is beyond our power to reproduce it again. *We cannot artificially produce the organic acids from their elements.* We are still ignorant how they are formed in plants and animals. All that is known on this point concerning the vegetable acids is, that they are formed from carbonic acid and water, the two chief sources of the nourishment of vegetables. But by what power, and in what manner, these two bodies are forced to combine in the grape-vine to form tartaric acid, in the fruit of the lemon-tree to form citric acid, in apples to form malic acid, &c., we are entirely ignorant. We here stand, as it were, on the boundary line of our knowledge; whether it will be permitted to us at some future period to advance beyond this limit, further investigations must show. In the mean time we must assume that the unknown power which causes the shoots, leaves, and blossoms, to put forth from the seeds,—we

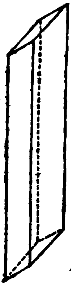
call it vital power,—is also able to produce chemical combinations and decompositions more powerful and manifold than it is possible for the chemist to accomplish in his retorts and crucibles. In this sense we regard the organic acids, as in general all organic substances, as the ***chemical productions of the vital activity*** of plants and animals.

The organic acids are briefly designated by a horizontal line placed above their initials. The Latin name for tartar is *tartarus;* the symbol for tartaric acid is $\bar{T}$.

OXALIC ACID ($H\,O, \bar{O}$, or $H\,O, O_2\,O_3$).

196. *Experiment.*—Heat with free access of air, in a porcelain dish, one fourth of an ounce of sugar, mixed with one and a half ounce of concentrated nitric acid, and one ounce of water. In a short time a strong evolution of yellowish-red fumes ($N\,O_3$) will commence. Continue boiling until these vapours cease, and then put the liquid in a cool place; colourless crystals (oblique rhombic prisms) will be separated, which must be purified by recrystallisation. They have an intensely strong acid reaction, and are poisonous; they are called *oxalic acid.* This acid, like most acids, contains water chemically combined, without which it cannot exist.

Fig. 105.



Experiment.—Pour into a test-tube twenty grains of oxalic acid, and one drachm of fuming sulphuric acid, and carefully heat the mixture; a gas will be evolved. Let this pass through lime-water contained in another test-tube. One half of the escaping gas is absorbed by the lime-water, which thereby becomes turbid; this is carbonic acid ($C\,O_2$). The other half escapes through the open tube, and burns, when kindled, with a bluish flame; this is carbonic oxide gas ($C\,O$). When the evolution of gas ceases, there will be found in the first test-tube common sulphuric acid; consequently, the fuming sulphuric acid has received water, namely, the chemically combined water contained in the oxalic acid. The oxalic acid, when it loses its water, is resolved into the two gases just mentioned; it may, accordingly, be regarded as a combination of

$$\begin{array}{r} 1 \text{ atom } C\ O_2, \\ \text{and } 1 \text{ atom } C\ O, \\ \hline \text{or } C_2\,O_3. \end{array}$$

On comparing this constitution with that of sugar, it will be seen that the sugar contains still more carbon than the oxalic acid, besides some hydrogen; consequently a portion of its carbon, and all its hydrogen, must have been withdrawn. This was done by the oxygen of the nitric acid, which oxygen, uniting with the carbon, formed carbonic acid, and with the hydrogen, formed water. This process may be regarded as a combustion (oxidation) in the moist way. Sugar has exactly the same constituents as wood. If a wood-shaving be ignited, at first the hydrogen principally burns, because it is very readily combustible; at last principally the carbon, because this burns with more difficulty. (§ 120.) The same succession of phenomena also takes place on the boiling of sugar with nitric acid; the hydrogen is at first principally oxidised, and afterwards the carbon; but the latter only partially, on account of the insufficient supply of nitric acid, just as wood is only partially consumed when there is a deficiency in the supply of the air. The partly consumed wood (charcoal) burns completely if we heat it still longer in the air; it is converted into carbonic acid by the oxygen of the air. Partly burnt sugar (oxalic acid) consumes completely when we boil it with still more nitric acid; it is converted into carbonic acid by the oxygen of the nitric acid.

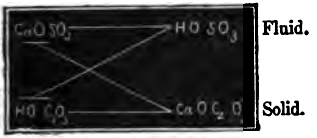
197. *Experiments with Oxalic Acid.*

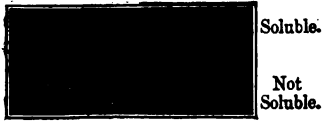
Experiment a.—Place some crystals of oxalic acid upon a piece of platinum foil, and hold them in the flame of a spirit-lamp. They melt, take fire, and burn *without becoming black* or leaving any residue. The product of the combustion is carbonic acid; $C_2\,O_3$ and O (from the air) are converted into $2\,C\,O_2$.

Experiment b.—Neutralise a hot concentrated solution of oxalic acid with a hot concentrated solution of carbonate of potassa; neutral oxalate of potassa ($K\,O,\ C_2\,O_3$), an easily soluble salt, is formed. If you now add as much more oxalic acid, hard crystals will be deposited on cooling, which have an acid reaction; they are called acid oxalate, or binoxalate of potassa. One atom of potassa can thus combine with two atoms of acid. As has been previously stated, salts with two atoms of acid are called *acid salts*. The binoxalate of potassa is likewise formed by the vital process in many plants, and it is found abundantly in the leaves of the wood-sorrel (Oxalis), from which it may be obtained. The acid salt is far less soluble than the neutral.

Experiment c.—Heat some binoxalate of potassa upon platinum foil; like the tartar, it will be converted into carbonate of potassa, but *without being carbonised or blackened.* The oxalic acid is thereby converted, as above, into carbonic acid and carbonic oxide, and a portion of the former combines with the potassa.

Experiment d.—Agitate a little sulphate of lime with water and let the liquid settle; the decanted water contains a small quantity ($\frac{1}{500}$) of the sulphate in solution. If a solution of oxalic acid is poured upon this solution, you will soon obtain a precipitate of oxalate of lime; consequently oxalic acid has a greater affinity for lime than sulphuric acid has, since it is able to displace the latter acid. The decomposition takes place more rapidly and perfectly when the oxalic acid has been previously neutralised by ammonia ($N H_3$), because another body is thus presented to the sulphuric acid, for which the latter has a greater affinity than for the water; it becomes thereby more ready, as it were, to release the lime. Oxalic acid is the best test for lime and lime salts.





Experiment e.—Add some spoonfuls of water to a piece of green vitriol of the size of a pea, and moisten with the solution a piece of white blotting-paper; when this has imbibed the liquid, spread over it some ammonia. The ammonia withdraws the sulphuric acid from the green vitriol, and protoxide of iron must consequently be separated in and upon the paper, to which it imparts a greenish tinge. On drying, the protoxide of iron becomes converted into sesquioxide of iron, and the green colour is at the same time changed to yellow. In a similar manner, cotton, and other fabrics, are often dyed brown or yellow. Mix some oxalic acid with water into a thin paste, and dot the yellow paper with it in several places; the colour will soon disappear from these spots, and you obtain a white pattern on a yellow ground. Oxalic acid easily dissolves sesquioxide of iron, and both are removed by washing. Upon this is founded the important use of this acid in calico printing, as likewise its application for the removal of ink-spots from linen or paper. One of the principal constituents of ink is oxide of iron, which being dissolved by the oxalic acid, the black colour of the ink disappears also. This explains why, on removing ink-spots by oxalic acid or salt of sorrel (which acts in the same manner as the free acid) from yellow and brown articles of dress, the colour of which generally depends upon oxide of iron, the colour of the stuff also disappears.

ACETIC ACID ($H O, \bar{A}$).

198. Vinegar is likewise a vegetable acid. It is often formed spontaneously, when we do not want it, as when sweet or spirituous liquors, thin syrups, the juice of fruit, wine, beer, &c., remain exposed to the air. The sugar is gradually converted into alcohol, which becomes vinegar when access to the oxygen of the air is not prevented. But the method by which this takes place will not be considered until sugar and alcohol are treated of. We shall now merely describe the method of preparing strong acetic acid from crude vinegar.

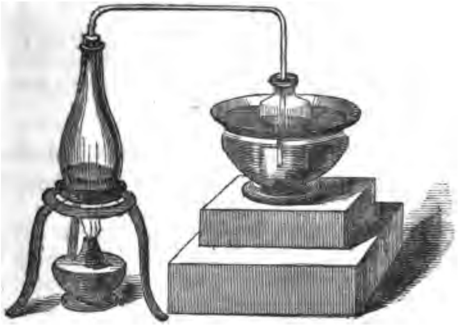
Our common vinegar contains in every pound only from half an ounce to two ounces of acetic acid; the rest is water. If you boil vinegar, the acid smell of the fumes indicates that the acid contained in it is volatile; therefore it cannot, like other acids, be made stronger by evaporation; but this may be done in the following manner.

Experiment.—Add to one pound of white vinegar an ounce or an ounce and a half of litharge (oxide of lead), and let the mixture stand in a vessel for some hours, in a warm place, stirring it frequently. The liquid will become clear on standing, and then if you evaporate it down to two and a half or three ounces, and let it cool, prismatic crystals of *acetate of oxide of lead* will be deposited. This salt is commonly called *sugar of lead*, from its sweetish taste. The acetic acid is held so firmly by the oxide of lead, that it can no longer escape with the steam during evaporation, or at least only in trifling quantities. Other bases may be substituted for the oxide of lead.

Experiment.—Place some sugar of lead upon a piece of charcoal, and heat it before the blow-pipe; the salt first melts in its water of crystallisation, then it becomes brown, and is finally carbonised; the acetic acid is thus decomposed, like tartaric acid on the heating of the salts of tartaric acid. If it is completely burnt, globules of metallic lead remain upon the charcoal. In this case the litharge is also decomposed; the red-hot charcoal abstracts from it its oxygen, and forms with this carbonic oxide gas, which escapes; consequently metallic lead must remain behind (reduction or deoxidation).

Experiment.—Mix cautiously half an ounce of sulphuric acid with half an ounce of water, and when cold pour the mixture into a flask containing one ounce of powdered sugar of lead. Now connect a glass tube and receiver with the flask, and distil the mixture at a moderate heat, on a sand-bath, until about three-fourths of an ounce of the fluid has passed over. Here we have an example of simple elective affinity; the strong sulphuric acid unites with the oxide of lead, and forms with it a white, insoluble compound, which remains in the flask, while the acetic acid, rendered volatile by the heat, is converted into vapour, which condenses in the cold receiver into liquid acetic acid.

Fig. 106.



The acid thus obtained is colourless, and has an exceedingly sour taste and smell. Solid crystals may be obtained from the strongest acetic acid (crystallisable acetic acid) by cold; a somewhat dilute acetic acid is called concentrated vinegar.

Experiment.—Add to strong acetic acid some drops of oil of cinnamon and cloves; if the acid is sufficiently strong they will *dissolve*. This mixture is called aromatic vinegar.

Experiment.—Pour some acetic acid upon a piece of lean meat, and it will gradually become soft and gelatinous. Common vinegar has also the same effect, but in a less degree; it is indeed well known, that meat impregnated with vinegar becomes very tender and digestible (soluble) when boiled or roasted.

Acetic acid cannot exist without the presence of water; seven ounces of the strongest acid contain one ounce of water chemically combined. The Latin word for vinegar is *acetum;* the symbol for acetic acid is, accordingly, $H\,O,\ \bar{A}$.

To detect the salts of acetic acid, heat them in a test-tube with concentrated sulphuric acid; when fumes having a very acid smell will be evolved.

RETROSPECT OF THE VEGETABLE ACIDS.

1. Almost all vegetable acids consist of carbon, hydrogen, and oxygen (oxalic acid being an exception).
2. They are generated during the growth of plants, in which they are found either free or combined with bases.
3. We cannot artificially prepare them from their elements, like the inorganic acids.
4. Some vegetable acids may indeed be also artificially imitated, but as a general rule this is effected by the metamorphosis of other vegetable substances.
5. All vegetable acids are carbonised by *heat*, and are at last completely burnt away (inorganic acids are not).
6. Most vegetable acids cannot exist without the presence of *water* (water of constitution); this water plays therein the part of a base.
7. Vegetable acids comport themselves towards bases like the inorganic acids; they form with them *salts*.
8. The vegetable salts are likewise decomposed by heat; the acid is carbonised and burnt away, while the base remains behind, usually combined with carbonic acid.

RADICALS.—CAPACITY OF SATURATION.

199. The word *radical* signifies root or base, and is often employed in chemistry to denote that substance which is regarded as the principal or fundamental constituent of a chemical compound. The metalloids unite with oxygen, and some of them also with hydrogen, forming acids; they are consequently regarded as the fundamental elements of the acids, and may be called the *acid radicals*. Sulphur is accordingly the radical of sulphuric acid; carbon, of carbonic acid; and chlorine, of chloric and muriatic acids, &c. With respect to the vegetable acids, which are composed of three elements, carbon, hydrogen, and oxygen, we may either assume the oxygen to be the acidifying principle, and then the carbon and hydrogen will be regarded as the acid radicals; or we might consider hydrogen to be the acidifying principle, then carbon and oxygen would be the radicals. In either case the radical consists of two elements; and for this reason the vegetable acids are said to be *acids with a compound radical*, in contradistinction to the mineral acids, which are regarded as *acids with a simple radical*, because they have only one element for their base. According to this classification, hydrocyanic and fulminic acids must be classed among the acids with compound radicals, since the radical cyanogen is composed of carbon and nitrogen.

This theory is also applied to bases and salts. The metals combine with oxygen, forming bases, and are, accordingly, the fundamental elements of the bases—*base radicals*. Iron, for example, is the radical of the oxide of iron, and calcium the radical of lime. The oxide or the base is regarded as the fundamental element of the salts; it has received the name *salt radical*. Protoxide of iron is, accordingly, the radical of green vitriol; lime that of chalk, &c.

200. It has already been demonstrated, by several experiments, that the acids are neutralised or saturated by bases, and also that every acid, on neutralisation, combines with a definite quantity only of a base. It now remains to be considered how large this quantity may be for every acid.

It has been ascertained, by accurate experiments, that 100 ounces of sulphuric acid require for neutralisation exactly

118 ounces of potassa, or 70 ounces of lime, or 90 ounces of protoxide of iron, or 278 ounces of litharge. Further researches have led also to the surprising discovery that these so unequal quantities of the different bases contain precisely the same amount of oxygen—namely, 20 ounces.

Sulphuric Acid				Oxygen
100 oz. are neutralised by	118 oz. of	potassa;	these contain	20 oz.
100 “ “	70 “	lime;	“	20 “
100 “ “	90 “	protoxide of iron;	“	20 “
100 “ “	278 “	oxide of lead;	“	20 “

It follows as a law for sulphuric acid, that 100 ounces of it require always for neutralisation a quantity of some base in which are contained 20 ounces of oxygen. Thus the number 20 has been called the *saturating power*, or *capacity of saturation* of sulphuric acid.

The action of bases upon all the other acids has been examined in the same manner, and the capacity of saturation of the latter determined. That of nitric acid, for example, is 14¾; that of carbonic acid, 36¼. That is, every quantity of any base containing exactly 14¾ ounces of oxygen, is able to saturate or neutralise 100 ounces of nitric acid. Every quantity of a base containing 36¼ ounces of oxygen is able to saturate or neutralise 100 ounces of carbonic acid.

Instead of comparing, as has been done here, the *acid* with the oxygen of the base, the *oxygen of the acid* is also sometimes compared with the oxygen of the base. This may be done very easily, if we only know, in the first place, how much oxygen is contained in 100 ounces of an acid.

		Oxygen		Oxygen
100 oz. of	sulphuric acid	contain 60 oz.,	and require in the base	20 oz.
100 “	nitric acid	“ 73¾	“ “	14¾ “
100 “	carbonic acid	“ 72½	“ “	36¼ “

And hence may be deduced the following simple proportion for the combination of the acids with the bases—that is, for the salts.

The *oxygen of the acid* bears the proportion to the *oxygen of the bases:*

In all neutral sulphates,	of 60	to 20,	or as 3	to 1
“ “ nitrates	“ 73¾	“ 14¾	“ 5	“ 1
“ “ carbonates	“ 72½	“ 36¼	“ 2	“ 1

Water acts also as a base when chemically combined with an acid. In common sulphuric acid ($H O, S O_3$), for example, the oxygen of the acid bears a proportion to the oxygen of the water as 3 to 1; in the strongest nitric acid ($H O, N O_5$), as 5 to 1, &c.

LIGHT METALS.

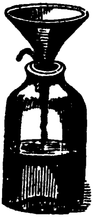
FIRST GROUP: ALKALI-METALS.

POTASSIUM (K).

At. Wt. = 40.—Sp. Gr. = 0.8.

201. *Potash, or Carbonate of Potassa* ($K O, C O_2$).

Fig. 107.



Experiment.—Fit into a funnel a filter of blotting-paper, and place upon it a handful of *wood ashes*, and gradually pour hot water over them. The liquid filtered through has an alkaline taste, and turns red test-paper blue. If you evaporate it to dryness in a porcelain dish, a grey mass finally remains behind, which becomes *white* after being heated to *redness* in a porcelain crucible; it is called *crude potash*. In those countries where wood is abundant—in America, Russia, &c.—it is prepared in a similar manner on a large scale, and is an article of great demand in commerce.

There are to be found in the ashes (§ 607) all the substances which the plants received from the soil during their growth. They are not volatile, and therefore remain behind, while the characteristic parts of the wood or plant are consumed. The soluble portion of the ashes is taken up by the water (potash and other soluble salts); those which are insoluble (silica, insoluble salts, and unburnt pieces of charcoal) remain behind on the filter.

Experiment.—Pour half an ounce of cold water upon half an ounce of commercial potash; stir it frequently, and let it stand for one night. Separate the liquid by filtration from the sediment, which consists principally of silica; evaporate it down to one-half, and again leave it in repose for one night, when most of the foreign salts will be deposited in crystals.

Again filter the liquid and evaporate to dryness, continually stirring with a glass rod, and you will obtain a white granulated mass—*purified potash.*

Potash is very easily soluble; therefore it is the first of the ingredients which is taken up by water, and the last which is separated from it; but the other admixtures are much less so, and they remain partly undissolved, and partly separate in crystals from the liquid, before the potash shows even the slightest tendency to crystallise. There are thus two methods by which substances of different degrees of solubility may be separated from each other.

202. *Experiments with commercial Potash.*

Experiment a.—Put one portion of potash in a vessel, and let it stand in a dry apartment, and put another portion in a cellar. The former becomes moist; the latter deliquesces. Both attract water from the air, but that in the dry atmosphere of the room less than that in the damp air of the cellar. Potash is a very *hygroscopic salt.*

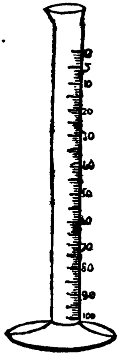
Experiment b.—Boil for some time, in a vessel containing a quarter of an ounce of potash and two ounces of water, a piece of grey linen, and some dirty or greasy linen or cotton rags; the liquid will become of a dark colour, while the rags are made white and clean. Dirt, as it is commonly called, is dust, which adheres to the skin, garments, &c., particularly after they have become moistened by perspiration, or have come in contact with greasy or other adhesive substances. These last-mentioned substances may be dissolved and removed by potash; on this depends the various application of this substance in cleaning and washing.

Experiment c.—Pour a tea-spoonful of potash into a tumbler containing vinegar; there escapes with brisk effervescence a gas, in which a burning taper is extinguished. This gas is the well known *carbonic acid;* it is chemically combined in the potash with the basic *oxide of potassium or potassa.* Potash is consequently a salt, *carbonate of potassa* (KO, CO_2); but beside this, the crude potash contains also several other foreign salts, as silicate, sulphate, muriate, and phosphate of potassa, and many others. The feeble carbonic acid is not able to destroy completely the basic properties of the potassa; therefore the carbonate of potassa has an alkaline taste, and colours red litmus-paper blue. Vinegar can completely neutralise potassa. If you add so much of it to the potassa, that neither blue nor red test-paper is altered, and then filter and evaporate the liquid, you will obtain a white saline mass,—*acetate of potassa.*

We might suppose that the carbonic acid, which so willingly assumes a gaseous form, might easily be expelled by heating; but it is a striking fact, that its friendship for the potassa stands the proof even of the hottest fire. The potash does not lose its carbonic acid at the strongest red heat.

The potash of commerce possesses very different degrees of goodness and purity. To test its value, or to compare several sorts with each other, weigh one hundred grains of each sort, and neutralise them with an acid. A good article requires more acid than a bad one; consequently, the value of the potash may be estimated according to the quantity of the acid consumed. An *alkalimeter* is a useful instrument for those who have frequently to determine the value of potash. It consists of a glass cylinder, divided into degrees (*graduated*), in which the quantity of acid is measured instead of being weighed. For this purpose a test-acid must be prepared, of such a strength that one degree of it will exactly neutralise one grain of pure carbonate of potassa. The number of degrees of the acid consumed will then indicate at once the percentage quantity of pure carbonate of potassa in the sample tested. The value of soda may be ascertained in a similar way.

Fig. 108.



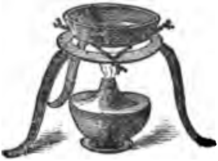
Bicarbonate of Potassa ($KO, 2CO_2 + HO$).

If carbonic acid is conducted into a solution of carbonate of potassa, the latter will take up as much again carbonic acid as it previously contained, and crystals will be deposited, consisting of one atom of potassa, two atoms of carbonic acid, and one atom of water. This combination belongs, accordingly, to the *acid salts*. On heating, the second atom of carbonic acid, together with the water, escapes; and the same happens, although more slowly, on boiling a solution of this salt.

203. *Oxide of Potassium, or Potassa* (KO).

If you withdraw the carbonic acid from the potash, potassa remains behind.

Fig. 109.



Experiment.—Place half an ounce of quick lime in a plate, sprinkle it with warm water, and let it stand until it is slaked, that is, until it becomes a fine dusty powder. Then put half an ounce of potash into an iron basin with six ounces of water, and boil it, and, during the boiling, gradually add half of the slaked lime by tea-spoonfuls, stirring it at the same time. After the mixture has boiled for some time, put a tea-spoonful of it upon a paper filter, and pour the filtrate into vinegar. If it effervesces, still more lime must be added; but if no effervescence ensues, pour the whole into a bottle, close it up, and let it remain quiet for some hours, that the sediment may subside. Decant the clear liquor, and preserve it in a well-stoppered bottle. It consists of water in which potassa is dissolved, and is called *solution of caustic potassa.* The carbonic acid previously combined with the potassa has during the boiling passed to the lime, as may easily be seen by the effervescence which ensues when vinegar or some other acid is poured on the white sediment of lime. From the lime, carbonate of lime is formed, but potassa from the carbonate of potassa. The carbonate of lime is insoluble, and is deposited as a white powder; the potassa is soluble, and combines with the water present.

It would thus appear as if lime were a stronger base than potassa, since it takes from the latter the carbonic acid; but this is not correct, for in all other cases the potassa is stronger than lime. *But a weaker base, when it forms with an acid an insoluble salt, always takes this acid even from a much stronger base.* Thus the lime abstracts the carbonic acid from the potassa, not because it has a greater affinity for the acid, but because it forms with it an insoluble compound (chalk). In the same way a weaker acid is often able to overcome a stronger one.

Experiment.—Evaporate a portion of the caustic potassa in an iron vessel (glass and porcelain are attacked by it); all the water but one atom escapes, and a white mass finally remains behind, *hydrate of potassa.* This may be melted at a stronger heat, and cast into sticks or plates (*lapis infernalis*, or fused potassa).

Potassa consists of a metal (potassium) and oxygen. (§ 166.) It also contains one-sixth of its weight of water, which cannot be expelled even by the strongest heat; its proper name is, accordingly, hydrate of potassa (K O, H O). This water is chemically combined with the potassa just as if it were an acid. Water, being an indifferent body, acts *with strong bases like an acid, and with strong acids like a base.* (§ 200.)

204. *Experiments with Hydrate of Potassa.*

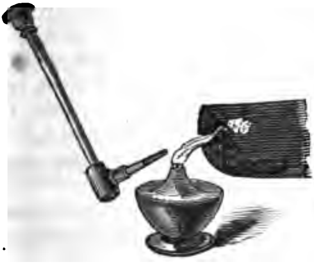
Experiment a.—Expose some dry potassa to the air; it will soon become moist; indeed, it will deliquesce, and on longer exposure it will effervesce upon the addition of an acid. Potassa has two strong affinities: 1st, for *water;* 2nd, for *carbonic acid.* It absorbs both from the air, and is then converted into carbonate of potassa.

Experiment b.—Heat in one test-tube some white, and in another some brown blotting-paper, with some solution of caustic potassa; both papers will be decomposed and dissolved, the vegetable fibres of the white paper (linen or cotton) more slowly than the animal fibres of the brown paper (wool). Potassa exerts a very *corrosive* action, especially on animal substances. The slippery feeling caused by rubbing lye between the fingers is owing to a gradual solution of the skin.

Experiment c.—Boil in a test-tube a little tallow or fat with a solution of caustic potassa; a union gradually takes place; soap is formed. The soap prepared from potassa remains soft, and is called soft-soap.

Experiment d.—If some potassa be melted with sand on a piece of charcoal, before the blow-pipe, we obtain a vitreous, amorphous compound of silicate of potassa. Much sand with a small proportion of potassa yields an insoluble glass—the common bottle or *window glass;* but much potassa with a small proportion of sand, a soluble compound, called *soluble glass.* A solution of the latter may be employed as a

Fig. 110.



fire-proof varnish for wood, canvas, and other combustible materials.

Experiment e.—Dissolve a piece of blue vitriol (sulphate of copper) in water, and add to it some solution of caustic potassa. Potassa is the *strongest base* known; therefore it abstracts the sulphuric acid from the blue vitriol, and forms with it sulphate of potassa, which remains in solution. The oxide of copper, not being soluble in water without an acid, is precipitated as a hydrate; that is, chemically combined with some water in the form of a delicate blue powder, and may be collected on a filter. This method is very frequently employed for separating metallic oxides from metallic salts.

205. *Potassium* (K).

If the oxygen is withdrawn from the potassa, then *potassium* remains behind,—a metal which has so strong a tendency to combine again with oxygen, that it can only be protected against oxidation by keeping it in mineral naphtha, a liquid which contains no oxygen.

The usual method of preparing potassium is by putting carbonate of potassa and charcoal into an iron bottle, provided with an iron exit-tube, and exposing them to the strongest white heat. At this extremely high temperature the charcoal combines with the oxygen of the carbonic acid and of the potassa, forming carbonic oxide gas, which escapes. The liberated potassium is also converted into vapour, which is conducted into naphtha, where it condenses into a solid mass, resembling silver.

It has been shown, under carbonic acid (§ 166), that potassium, at a moderate heat, can withdraw the oxygen from the carbon; while here, at a higher temperature, the contrary takes place. Similar incongruities in chemical actions are not unfrequent; they show that the affinities of bodies for each other are greatly altered by the temperature.

Experiment.—Put a piece of potassium of the size of a pea into a basin of water; it *floats* with a hissing noise upon the water, and *burns* at the same time with a lively reddish flame. After the combustion is finished, the potassium has apparently vanished; but it is in fact in solution in the water, being, however, no longer potassium, but potassa, as we may easily ascertain by red test-paper, the colour of which will now be changed by the water to blue. Consequently it has, during the combustion, combined with oxygen; this oxygen it took from the water, and so much heat was thereby evolved that the second constituent of the water, hydrogen, was inflamed.

If a piece of potassium is cut with a knife, it presents a glistening surface like silver; but it immediately tarnishes on exposure to moist air, and soon becomes converted into a white body, hydrate of potassa. In this case it takes the oxygen from the air.

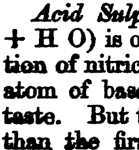
Salts of Potassa.

Salts are produced, as has been before stated, when a base combines with an oxygen acid or a hydrogen acid (oxygen salts and haloid salts). As there are hundreds of acids, so also hundreds of potassa salts may be prepared. But those only will here be considered which are of especial importance in science, the arts, or the common uses of life.

206. *Sulphate of Potassa* (KO, SO_3).

Dissolve half an ounce of potash in two ounces of warm water, and neutralise with diluted sulphuric acid; evaporate the filtered liquid till a film appears on the surface, then let it remain quiet for one day. The hard crystals obtained (six-sided double pyramids) are sulphate of potassa; they are sparingly soluble in water, and have a somewhat bitter taste. This salt forms a constituent of the well-known alum.

Fig. 111.



Acid Sulphate, or Bisulphate of Potassa ($KO, 2SO_3 + HO$) is obtained as a secondary product in the preparation of nitric acid from saltpetre. (§ 159.) It contains one atom of base and two atoms of acid, and has a very acid taste. But the second atom of acid is more feebly combined than the first, and may be expelled by the application of strong heat.

207. *Saltpetre, Nitre, or Nitrate of Potassa* (KO, NO_5).

Dissolve half an ounce of carbonate of potassa in one ounce of hot water, and neutralise with nitric acid; afterwards boil and filter the liquid, and set it aside to cool; prismatic crystals of nitre will be deposited from it, which have a cooling taste, and undergo no alteration in the air.

Fig. 112.

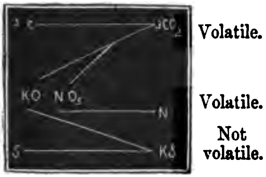
Experiments with Nitre.

Experiment a.—Heat some nitre in a test-tube; it melts; if you pour it by drops upon a cold stone, you will obtain globules of nitre. Upon the application of a stronger heat, oxygen will escape, and afterwards nitrogen; consequently, the nitric acid is thereby resolved into its two elements.

Experiment b.—If you throw a little nitre on a glowing coal, it will sparkle briskly; it deflagrates. In this case, also, the nitric acid is decomposed, and its sudden conversion into two gases is the cause of the sparkling. The oxygen, becoming free, finds in the coal a body with which it can combine; the escaping gases are, accordingly, *carbonic acid* and *nitrogen*. A portion of the carbonic acid formed combines with the potassa, which remains behind. From $K\,O$, $N\,O_5$, and $2\frac{1}{2}\,C$, are formed $K\,O$, $C\,O_2$, and $1\frac{1}{2}\,C\,O_2$. The hard saline mass, congealed from its melted state, remaining on the coal, has a basic reaction, and effervesces with acids; it is carbonate of potassa, or potash. In order to render substances more inflammable, they are often soaked in a solution of nitre; as, for example, tinder, &c.

Experiment c.—Mix thoroughly in a mortar six drachms of powdered nitre, one drachm of charcoal-powder, and one drachm of sulphur; this is *pulverised gunpowder*. Take a little on the point of a knife, put it on a stone, and ignite it with a match; a brisk deflagration will ensue. Knead the rest of the powder, with some drops of water, into a paste, and squeeze it through a tin colander. The thread-like mass thus obtained is, when partly dry, divided into small grains by gently rubbing with the fingers; this is gunpowder.

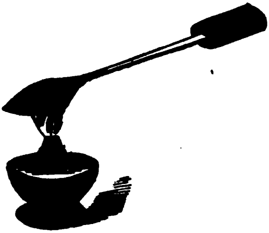
Experiment d.—Place some gunpowder upon an iron plate, and ignite it; the explosion follows even more quickly than with the pulverised gunpowder, because the granulated gunpowder is less compact than the pulverised. In this, as in the former deflagration, there are also evolved from the charcoal and the nitric acid *carbonic acid* and *nitrogen*, two gases which instantly occupy a space several thousand times greater than before. Sulphur not only causes an easier ignition of the gunpowder, but it causes also a stronger evolution of gas; since it combines with the



potassium of the nitre, forming sulphuret of potassium, whereby three atoms of free carbonic acid are evolved, while in experiment *b* (without sulphur) only an atom and a half of this gas has been set free. If the deflagration of the gunpowder takes place in a confined space, as in a gun-barrel, the *explosive* violence with which the two gases are suddenly expanded is strong enough either to project the ball or to burst the gun. The sulphuret of potassium remaining on the iron plate soon becomes moist in the air, and then emits the odour of sulphuretted hydrogen (§ 133); at the same time, the iron is blackened by the formation of sulphuret of iron upon the surface. The same occurs in the case of the iron barrel of the gun.

Experiment e.—Mix twenty grains of iron filings with ten grains of nitre, and heat the mixture in an iron spoon, the handle of which has been fixed in a cork; a brisk ignition of the mixture will ensue; the iron will be oxidised by the oxygen of the nitric acid, while the nitrogen escapes. The potassa remaining behind may be dissolved by water. Nitre is on this account well adapted for converting metals into metallic oxides.

Fig. 113.



f.—If nitre be heated with sulphuric acid, the nitric acid escapes. (§ 159.)

g.—Animal substances are preserved from putrefying by nitre; it is therefore used in salting meat.

The manufacture of nitre is conducted in a very peculiar manner. Animal substances, for instance, pieces of flesh, hides, hair, &c., are mixed with lime and earth, and then moistened with water or urine, and suffered to putrefy slowly. Animal substances are rich in *nitrogen*, which, during putrefaction, is set free in the form of ammonia ($N H_3$); this, after a time, unites with the oxygen of the air, forming nitric acid (and water), which acid is immediately neutralised by the lime. If animal substances decay without the presence of lime, or some other strong base, no nitric acid, but only ammonia, will be produced; *consequently, it is the strong base which disposes the nitrogen to combine with the oxygen.* (§ 146.)

After the completion of the putrefaction, add water to extract the soluble matter, and a solution of nitrate of lime is obtained, which is converted by carbonate of potassa into soluble nitrate of potassa, and insoluble carbonate of lime. Nitre-beds, so called, are prepared in this way. We also obtain nitre from the East Indies, where it is spontaneously generated in many limestones containing potassa.

208. *Chlorate of Potassa* ($K\,O,\,Cl\,O_5$).

This salt, as its formula indicates, may be regarded as a brother of nitre; but its disposition, compared with that of the latter, is far more intractable and violent, since chloric acid is much more easily decomposed than nitric acid.

Experiments with Chlorate of Potassa.

Experiment a.—Chlorate of potassa is, by merely heating, very easily resolved into oxygen and chloride of potassium; therefore it is used in the preparation of oxygen, as was described in § 59.

Experiment b.—When thrown on glowing coals, it deflagrates still more briskly than nitre; the oxygen, as it is liberated, occasions a very energetic combustion of the coal. This salt cannot be employed in the preparation of gunpowder, as the rapidity with which it explodes would be too much for the guns; yet, on this very account, it is extremely serviceable in fireworks, especially for producing variegated fires. The *greatest caution* must be observed in pulverising and mixing it, as it may explode by merely rubbing or pounding it. *When it is to be ground fine, it should always be previously moistened with some drops of water;* the mixing of it with other substances must always be done with the fingers.

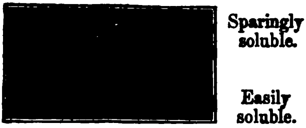
Experiment c.—Introduce some crystals of chlorate of potassa into a beaker-glass, and add a small quantity of alcohol, and afterwards a few drops of sulphuric acid; the sulphuric acid expels the chloric acid, which is immediately decomposed, and there is so great an evolution of heat as to set fire to the alcohol.

Experiment d.—Mix some chlorate of potassa between the fingers with about half as much flowers of sulphur, and throw the mixture into sulphuric acid, contained in a beaker-glass; a brisk crackling ensues, and the sulphur takes fire. This experiment is daily performed, though in a somewhat different way, in every German household, although not exactly with the view of studying chemistry. Every one performs it who ignites a match by means of the lucifer-match bottle. The red mass on the end of the match consists of chlorate of potassa and sulphur, which has been coloured red by cinnabar; and the bottle contains asbestos, moistened with sulphuric acid. The asbestos merely serves to prevent the too deep immersion of the match. 10 parts of sulphur, 8 of sugar, 5 of gum arabic, 2 of cinnabar, and thirty of finely powdered chlorate of potassa, form with water a good inflammable mass, with which the piece of wood previously dipped in melted sulphur is coated.

e.—Chlorate of potassa, like nitre, oxidises the metals on being heated with them.

f.—If you heat chlorate of potassa with muriatic acid, chlorine escapes. This does not proceed, however, from the chlorate of potassa, but from the muriatic acid, which is deprived of its hydrogen by the oxygen of the chloric acid, in the same manner as it was by the oxygen of the manganese, or of the nitric acid.

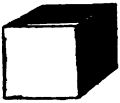
Chlorate of potassa is prepared by passing chlorine into a hot solution of potassa; the process is illustrated by the annexed diagram: two salts are formed simultaneously, chloride of potassium and chlorate of potassa; the first is easily, the latter more sparingly soluble in water; they may, therefore, be separated from each other by crystallisation.



Silicate of Potassa is the principal constituent of most rocks and of glass. (§ 204.)

209. *Chloride of Potassium, or Muriate of Potassa* ($K\,Cl$). Dissolve half an ounce of carbonate of potassa in water, and neutralise with muriatic acid; upon concentrating the solution, cubic crystals will be obtained, having a taste similar to common salt. They consist of potassium and chlorine, and if dissolved in water they may be regarded as muriate of potassa, $K\,Cl + H\,O$, being the same as $K\,O, H\,Cl$.

Fig. 114.



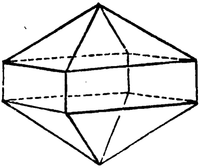
210. *Iodide of Potassium, or Hydriodate of Potassa* ($K\,I$). This salt likewise crystallises in cubes, is easily soluble in water, and is employed in medicine as a valuable remedy.

Experiment.—To prove that iodine is really contained in this white salt, heat a small portion of it in a test-tube with a little black oxide of manganese and some drops of sulphuric acid, when violet fumes will be evolved. If common salt is treated in the same manner, chlorine, as is known, will be given off. The chemical action is the same in both cases.

211. *Tartar, or Bitartrate of Potassa* ($K\,O, 2\,\overline{T} + H\,O$).

Common sorrel, the shoots of grape-vines, unripe grapes, &c., have an acid taste; they contain an acid salt, tartar. (§ 195.) These plants absorb the alkali from the soil, but by some unknown process they prepare the tartaric acid by means of their own organisation. Ripe grapes also contain tartaric acid, but the sour taste is concealed in them by the sweet taste of sugar, and we do not perceive it until the sugar is converted by fermentation into alcohol; that is, until the must is converted into wine. A great part of the tartar is deposited in the wine-casks as a hard, grey, or red crust (crude tartar). When this is purified from colouring matter by recrystallisation, we obtain a white tartar (purified tartar). The powder of it is well known under the name of cream of tartar. Tartar is very sparingly soluble in water. That it burns on heating, forming carbonate of potassa, has been already shown under tartaric acid. *Pure* carbonate of potassa is commonly prepared from tartar.

Fig. 115.



Neutral Tartrate of Potassa ($K\,O, \overline{T}$).

To prepare this salt, dissolve half an ounce of pure carbonate of potassa in two and a half ounces of water, then add one ounce of purified tartar, and let the mixture stand for a day in a warm place, frequently stirring it. The filtered liquid, after sufficient evaporation, yields prismatic crystals, or, when evaporated to dryness, a white powder. This salt is very easily soluble, but is also very easily decomposed by other acids, even by very feeble ones. On mixing a solution of it with vinegar, a white powder (cream of tartar) is precipitated. The second atom of the base is very easily abstracted by other acids, and thus the sparingly soluble acid salt, tartar, is again formed.

As in the above experiment, the second atom of the acid in the tartar was neutralised by potassa, so we can also neutralise it by other bases. We obtain in this manner double salts, several of which are used as valuable medicines.

Tartrate of potassa + tartrate of water = cream of tartar.
" " + " soda = Rochelle salts.
" " + " ammonia = ammoniated tartar.
" " + " peroxide of iron = tartarised iron.
" " + " oxide of antimony = tartar emetic.

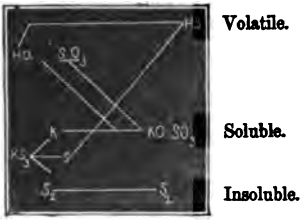
212. *Salt of Sorrel, Acid Oxalate, or Binoxalate of Potassa* $(K\,O, 2\,C_2\,O_3 + 2\,H\,O)$.

The leaves of the wood-sorrel have a sour taste, and contain also an acid salt, the base of which is likewise potassa; the acid, however, is not tartaric, but oxalic acid. In those places where the sorrel grows abundantly, the juice is expressed, and the salt is obtained, by evaporation and crystallisation, in white, sparingly soluble crystals. It has already been noticed. (§ 197.) It is in common use for removing ink-spots from linen.

213. *Liver of Sulphur, or Tersulphuret of Potassium* $(3\,K\,S_3 + K\,O, S\,O_3)$.

Experiment.—Put a mixture of one drachm of sulphur and two drachms of dry carbonate of potassa into an iron ladle, cover it with a strip of sheet-iron, and heat it until the effervescence has ceased and the mass flows quietly. The fused mass has the colour of liver, and on this account has received the name *liver of sulphur;* pour it upon a stone, and if it should inflame, cover it with a vessel to extinguish it. On exposure for some time to the air it becomes greenish and moist, and evolves an odour like that of rotten eggs. The simple sulphur cannot combine directly with the compound carbonate of potassa, but it can do so if the latter surrenders its carbonic acid and its oxygen. This does take place. The carbonic acid escapes with effervescence, while the oxygen combines with one quarter of the sulphur, forming sulphuric acid, which unites with a portion of the undecomposed potassa, forming sulphate of potassa; accordingly, the liver of sulphur is a mixture of *tersulphuret of potassium* and *sulphate of potassa.*

Experiment.—Pour water into a test-tube containing some liver of sulphur; you obtain a yellowish-green solution. If to this you add diluted sulphuric acid, a strong evolution of *sulphuretted hydrogen* takes place, and the liquid becomes milky from the precipitation of two-thirds of the sulphur (milk of sulphur). A decomposition of water hereby takes place; the oxygen of the water converts the potassium into potassa, which unites with the sulphuric acid, but the hydrogen escapes, with one-third of the sulphur, as sulphuretted hydrogen. The same thing is effected, though far more slowly, by the carbonic acid of the air, and thus is explained why the liver of sulphur (as well as the residue left on the combustion of gunpowder) emits a smell like that of rotten eggs when it is left exposed to the air.



The liver of sulphur is chiefly used for preparing sulphur baths. A similar preparation is obtained in the moist way, as has been described. (§ 129.)

Besides this combination of *potassium* with *sulphur*, there are several others, containing either more or less sulphur. The simplest compound of sulphur and potassium (K S) is obtained by heating together sulphate of potassa and charcoal, which latter abstracts the oxygen both from the potassa and from the sulphuric acid, forming with it carbonic oxide, which escapes. In the same manner all sulphates are converted into *sulphurets* by heating them with charcoal.

214. *Potassa Salts as Manure.*—The salts of potassa exercise a very beneficial influence upon the fertility of the soil, and are particularly adapted for those plants, in the ashes of which, when burnt, the potassa salts are found; namely, for the grape-vine, potatoes, turnips, &c. Such plants may be called *potassa plants.* It is now known that plants do not flourish even in the richest soil, unless they find in it certain bases (potassa, lime, &c.), and also certain acids

(silicic, phosphoric, sulphuric, &c.) In order to ascertain what acids and bases, or, in other words, what salts, are required for the cultivation of a certain plant, it is merely necessary to burn this plant and examine the ashes. The substances which are found, though their amount is generally but very small, must be regarded as *indispensable to the nourishment of this plant.* If the soil is destitute of potassa, neither turnips nor grape-vines will flourish in it; if destitute of lime, it will produce neither clover nor peas. By the addition of potassa salts we can restore to such a soil its fertility for the potassa plants, and by the addition of lime we again render it productive for the lime plants. On this is founded the application of the so-called *mineral manure* (lime, gypsum, wood-ashes, salt, &c.) to our fields. Common dung, also, and the liquid which flows from it, operate partly in the same way, since they are rich in phosphoric acid, as well as in alkaline and in lime salts. If turnips are cultivated season after season upon the same field, the potassa will finally become exhausted, and turnips will no longer grow there; the same thing happens when peas are planted year after year upon the same land, as they will at last exhaust all the soluble lime from the soil. But turnips will flourish in this latter field, because it still contains potassa, and peas in the former field, where lime is still present. Thus is explained, in a very simple manner, the advantage of the *rotation of crops*, which has been universally introduced into agriculture.

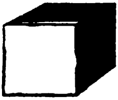
SODIUM (Na).

At. Wt. = 23.—Sp. Gr. = 0.9.

Common Salt, Chloride of Sodium, or Muriate of Soda (Na Cl).

215. *Experiment.*—Dissolve one ounce of salt in two ounces and three-fourths of cold water; the water will dissolve no more, even if added. Repeat the experiment, using hot instead of cold water; the result is precisely the same. Common salt has the remarkable property of *being equally soluble in hot and in cold water.* A larger quantity of almost all other salts is dissolved by hot than by cold water. Put one of these solutions in a warm place; by the gradual

Fig. 116.



evaporation, regular transparent crystals of common salt are formed. Boil down the other solution, quickly stirring it all the while; it yields a granular, opaque, saline powder (disturbed crystallisation). Salt is prepared as last described on a large scale, and hence the granular state of common salt.

Experiment.—If you expose a solution of salt in an open place during the extreme cold of winter, transparent prismatic crystals will be formed, which contain more than one-third of water. When placed on the hand they quickly become opaque and deliquesce into a syrupy mass, in which numerous small cubic crystals may be perceived. This experiment shows verly clearly,—

1.) How one and the same body may assume different forms at different temperatures; at common temperatures salt crystallises in anhydrous cubes, but under the influence of cold in hydrated prisms.

2.) How great an influence temperature exerts upon the affinities of bodies for each other. At a temperature above the freezing point, salt has no affinity for water; we obtain anhydrous cubes; below the freezing point it has an affinity for water, and we obtain prisms which consist of a chemical combination of salt and water.

3.) How easily chemical bonds of affinity may be destroyed again; the heat of the hand even is sufficient to destroy the affinity of salt for water.

Experiment.—Heat some common salt on platinum foil; it will crackle briskly, and part of it will be thrown off the foil; that which remains *melts* when the foil becomes red-hot. The crackling proceeds from a trace of water (water of decrepitation), which has remained in the interstices of the crystals; on being heated it expands and bursts the crystals asunder.

Salt has been previously twice artificially prepared; namely, once from sodium and chlorine (§ 153), and again from soda and muriatic acid (§ 186); its constituents are accordingly already known. It has the formula Na Cl. If water is present, it may be regarded also as muriate of soda, for $Na\,Cl + H\,O$ is equal to $Na\,O, H\,Cl$.

216. The earth and sea abound in common salt; it may

therefore be easily procured in large quantities. In many places it is found in the interior of the earth, in immense beds, from which it is broken up and dug out. This salt looks like a transparent stone, and is, therefore, called *rock-salt*. In those places where the rock-salt is mixed with stones and earth, a hole is bored in the middle of the bed, and water is let into it. The water is pumped out again as soon as it has become saturated with the salt, and is again expelled by evaporation. In some places springs are found containing salt in solution, the so-called *natural brine springs*. These are always occasioned by the water permeating the earth over a bed of rock-salt, and appearing as a spring at some lower level.

As the *natural springs* commonly contain much more water than is necessary for the solution of the salt, a cheaper method than that of fire, namely, a current of air, is first employed for the evaporation of it. The salt water is pumped up to the top of a lofty scaffolding (*graduation-house*), filled up with bundles of thorns, and from which it is made to fall by drops through the thorns. It diffuses itself over the branches, and thus presents a very large surface to the air passing through, whereby very rapid evaporation is effected. All natural salt waters contain sulphate of lime in solution; this is deposited first, since it is difficultly soluble, and encases the branches with a hard crust. When the greater portion of the water is evaporated, the concentrated brine is finally boiled down with constant stirring in large pans, and the granular salt, which separates, is raked out and dried. During the evaporation, a solid incrustation is deposited at the bottom of the pans, consisting principally of Glauber salts and sulphate of lime, and from which Glauber salts are extracted. Finally, a somewhat thick liquid remains, the so-called mother-water, from which no more salt can be extracted; it contains the easily soluble foreign salts present in the brine, namely, chlorides of calcium and magnesium, and bromide of magnesium, and is used for baths and for the preparation of bromine.

In hot countries, salt is also prepared from sea-water, which is evaporated in shallow tanks by the heat of the sun. It is called *bay-salt*, and has a bitterish taste, owing to the presence of salts of magnesia. A pound of sea-water contains from one-half to five-eighths of an ounce of common salt.

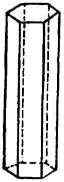
217. Small quantities of common salt are found in almost every spring of water, in every soil, in every plant. Is this universal diffusion of salt to be regarded as accidental? By no means. This is one of the spiritual advantages to be derived from the study of the natural sciences, that they lead us to recognise in the wonderful arrangements of nature, not the sport of chance, but the forming hand of an Eternal Wisdom. We find common salt everywhere in nature, because it is indispensable to the life of animals and plants. Without salt, no complete digestion of food could take place, and therefore we justly regard it as a universal condiment. Animals find it in the flesh and plants by which they are nourished; plants receive it from the soil and rain, and it is well known that we can promote the fertility of our fields by the application of a coarse kind of salt.

Salt is also used for preserving animal and vegetable substances, it having the power of preventing chemical decompositions, or, in common language, putrefaction or decay. Meat and fish are salted down, and wood for the purpose of building is rendered more durable by being impregnated with salt.

218. *Glauber Salts, or Sulphate of Soda* ($Na\ O, S\ O_3 + 10\ H\ O$).

As most of the potassa salts, potassa, and potassium are prepared from carbonate of potassa, so most of the soda salts, soda, and sodium are prepared from common salt. In the latter case, however, an indirect process must often be resorted to, since chlorine is not so easily removed from sodium as carbonic acid is from potassa. The chloride of sodium must first be converted into *sulphate of soda.* We are already acquainted with this salt, it having remained in the retort after the preparation of muriatic acid (§ 185), where common salt was heated with sulphuric acid. It was formerly taken as a popular medicine, under the name of Glauber's salts, so called from its discoverer, the physician, *Glauber.* We find it also in many mineral waters; for instance, in the Cheltenham and Carlsbad waters, and in the

Fig. 117.



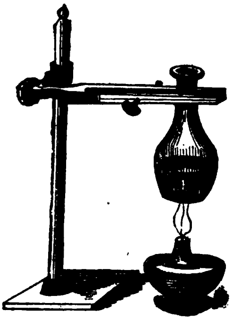
incrustation of the salt-pans, as was mentioned under common salt. It is readily soluble, crystallises in four or six sided prisms, and has a saline bitter taste.

Experiment.—Place half an ounce of transparent crystallised Glauber salts in a warm place; they soon become covered with an opaque white coating, and finally crumble into powder; they *effloresce.* The powder obtained weighs hardly a quarter of an ounce. That which was lost was water. Glauber salts contain more than half their weight of water of crystallisation. It is thus obvious that it is this chemically combined water which imparts to the salt its form and transparency, both of which are lost when the water is evaporated by the heat; but they reappear when the pulverulent anhydrous salt is dissolved in boiling water, and the solution allowed to cool. Carbonate of potassa is a *deliquescent* salt, common salt is a *permanent* salt in the air, while Glauber salts are *efflorescent.* Salts which effloresce must be kept in a cool place, well corked up.

Experiment.—If a crystal of Glauber salts is heated on charcoal before the blow-pipe, it soon melts, because it dissolves in its water of crystallisation (watery fusion); it becomes dry as soon as the water is expelled; but finally it melts for the second time when heated to redness (igneous fusion). Those salts which contain no water of crystallisation undergo only the latter kind of fusion.

Experiment.—Heat in a small flask half an ounce of water to 91° F. (33° C.), and keep it at this temperature, gradually adding crystallised Glauber salts, as long as they are dissolved, amounting to about an ounce and a half. If a stronger heat be now applied to the saturated solution, a salt will separate (anhydrous crystals); if you let it cool, a salt will likewise separate (hydrated crystals);—furnishing another example of the great influence exerted by temperature on the affinity of water for other substances. Glauber salts have the peculiar property of being most soluble in water, not at the boiling point, but at a lower temperature.

Fig. 118.

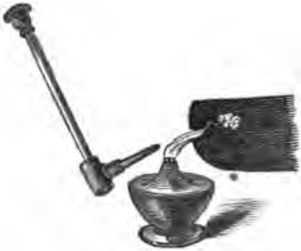


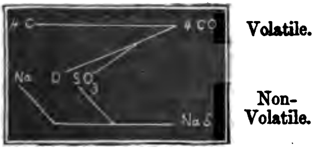
Experiment.—If you dissolve crystallised Glauber salts in water, *cold* is produced; but if, on the contrary, you dissolve anhydrous Glauber salts in water, then *heat* is produced. You will observe exactly the same phenomena if you perform this experiment with carbonate of soda, taking first the crystallised and then the calcined carbonate of soda. Whence the source of this heat? It comes from the *water*, because a part of the water combines with the anhydrous Glauber salts, or the anhydrous carbonate of soda, as water of crystallisation. Consequently, it is a phenomenon very similar to that which takes place in the slaking of lime. (§ 33.)

219. *Sulphuret of Sodium* (NaS).

Experiment.—Mix a small portion of anhydrous Glauber salts with a little charcoal powder, and heat the mixture on charcoal before the blowpipe; they will melt with brisk effervescence into a brown mass, which dissolves in water, forming a yellowish liquid. The charcoal, when heated to redness, abstracts the oxygen both from the soda and from the sulphuric acid, and forms with it carbonic oxide gas, which escapes with effervescence; sodium and sulphur remain behind, combined with each other. That is, the charcoal deoxidises the sulphate of soda, or reduces it to sulphuret of sodium.

Fig. 119.





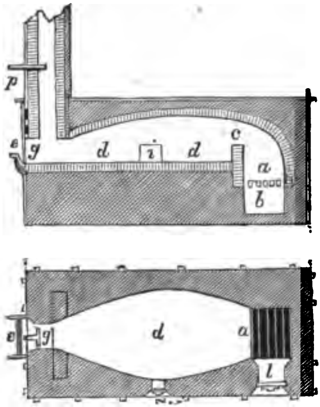
If you drop muriatic or diluted sulphuric acid into the solution, the disagreeable smell of sulphuretted hydrogen will be given off, just as in the case of liver of sulphur. (§ 215.) If you now let the liquid evaporate on a glass plate, you obtain, in the former case, small cubes of common salt, and in the latter, a pulverulent incrustation of Glauber salts.

220. *Carbonate of Soda* ($NaO, CO_2 + 10HO$).

Experiment.—Prepare some more sulphuret of sodium in the manner just described, rub it in a mortar with the adhering particles of charcoal and with about its own weight of chalk, and ignite it again before the blow-pipe. Boil the baked saline mass in water, and then filter the liquid. A grey powder remains behind, which, when drenched with muriatic acid, evolves sulphuretted hydrogen; it is sulphuret of calcium. The liquid, after being evaporated on a shallow glass dish, leaves behind a white powder, which has an alkaline reaction and effervesces with muriatic acid, but yet without emitting any disagreeable odour; it is carbonate of soda. The sulphur has thus passed to the calcium of the chalk, while the oxygen and the carbonic acid of the chalk have passed to the sodium. By these processes it will be seen that, as in the daily affairs of life, so also in chemistry, we can often obtain indirectly that which could not be gained directly. Sodium has a stronger affinity for chlorine than for oxygen; therefore we cannot prepare soda directly from common salt; but by means of sulphuric acid we can easily convert the haloid salt into an oxy-salt,—into sulphate of soda. The strong sulphuric acid cannot be directly expelled from this; we therefore first decompose it into oxygen and sulphur, and afterwards remove the sulphur by another metal, calcium, which forms with sulphur an insoluble compound. Soda is thus obtained, yet not in a free state, but as carbonate of soda; carbonic acid, however, is so feeble an acid, that it may easily be expelled by another acid, or by caustic lime.

As carbonate of soda possesses almost exactly the same properties as carbonate of potassa, and can be advantageously employed instead of the latter in washing and bleaching, and also in the manufacture of glass and soap, it is now manufactured on a large scale in chemical works. There are, in Germany, laboratories where from ten to twelve thousand hundred-weights of soda are annually made. The process pursued is essentially the same as that already described, ex-

Fig. 120.



cept that the two operations, described separately above, are united into one; the chalk or limestone is added, in the first place, to the Glauber salts and charcoal, and the whole mass is heated. This is done in a large oven-shaped furnace, represented in the figure. *a* is the grate, *b* the ash-pit, *p* the chimney, *d d* the hearth for receiving the mixture, *i* the aperture for throwing in the mixture, and *g* an opening for stirring it and scooping it out. They are called *reverberatory-furnaces*, because the heating is effected, not by the fuel itself, but by the flame, which is reverberated after passing over the bridge *c;* they possess this important advantage, that the ashes of the coal or peat do not become mixed with the substance to be heated. In many countries an impure soda is also obtained from the ashes of marine plants (kelp).

Carbonate of soda consists of equal atoms of soda and carbonic acid. It occurs in commerce, either *crystallised*—it then contains more than half its weight of water of crystallisation (10 atoms) and effloresces very readily—or *calcined*, consequently anhydrous. The latter, accordingly, when it occurs pure, is of more than twice the strength of the crystallised. Carbonate of soda is easily soluble in water. Many mineral waters—for example, the Carlsbad springs—contain great quantities of it in solution; Carlsbad salt, obtained by evaporating the waters of the spring, is a mixture of carbonate and sulphate of soda.

Bicarbonate of Soda ($NaO, 2CO_2 + HO$)

is more sparingly soluble than the former salt, and is frequently used in effervescing powders, because it evolves on being mixed with acids as much carbonic acid again as the simple carbonate. Effervescing powders are prepared by triturating together equal portions of tartaric acid and bicarbonate of soda. If you put this mixture into water, tartrate of soda is formed, and carbonic acid escapes. When heated, this salt comports itself like the bicarbonate of potassa.

221. *Soda, or Oxide of Sodium* (Na O).

If you take from the carbonate of soda its carbonic acid, soda will remain behind. This is done by boiling a solution of soda with quick lime, in the same manner as was described under potassa. (§ 203.) The liquid thus obtained is called *caustic soda lye*, and yields, after evaporation, *caustic soda.* This contains, like caustic potassa, yet one atom of water, which it does not part with even when heated to redness; hence it has been more correctly called *hydrate of soda* (Na O, H O). The hydrate of soda has a corrosive action, forms soap with fat, and hard glass when melted with sand; it is a very strong base, like caustic potassa, for which it is often substituted in preference in the arts.

222. *Sodium* (Na).

On abstracting oxygen from the soda, metallic sodium is obtained. This metal is prepared like potassium, which it greatly resembles, though it does not act so violently upon other bodies; for instance, upon water. Put upon cold water, it oxidises without flame, but put upon hot water, the escaping hydrogen ignites, and burns with a yellow flame.

We have now passed from the most widely diffused common salt to the element sodium, treating each one in that succession which it is necessary to pursue in the actual preparation of these substances. The following summary statement may serve to fix them on the memory:—From common salt, or chloride of sodium, sulphate of soda is prepared; from this, sulphuret of sodium; from this, carbonate of soda; then soda; and finally sodium.

A few other *salts* of soda will now be considered.

223. *Phosphate of Soda.*

Experiment.—Neutralise half an ounce of carbonate of soda, dissolved in water, with phosphoric acid prepared from bones; filter the liquid from the phosphate of lime which separates, and evaporate the filtrate until a film forms on the surface; on cooling, transparent crystals will be deposited, which contain more than half their weight of water of crystallisation. They easily effloresce, and yield a *yellow* precipitate with a solution of nitrate of silver.

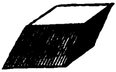
Experiment.—Let some of the crystals of the phosphate of soda effloresce in a warm place, and afterwards heat them to redness in a porcelain crucible. When the mass is cold, dissolve it in water, and evaporate the solution; you obtain a salt which contains far less water of crystallisation than the former one; it no longer effloresces, and yields with nitrate of silver a *white* precipitate; it has received the name of pyrophosphate of soda. This example shows how the affinity of a salt for water may be weakened by being heated to redness, and how the properties of a salt may be changed, according to the amount of water with which it is chemically united.

Fig. 121.

224. *Nitrate of Soda* (NaO, NO_5).

Experiment.—Dissolve half an ounce of carbonate of soda in a little hot water, and neutralise it with nitric acid; then evaporate the solution till a pellicle begins to form, when crystals will separate, having the form of an oblique rhombic prism; they are nitrate of soda. They deflagrate on charcoal like nitrate of potassa, only somewhat less violently, and have the greatest similarity to it in other respects. Large districts of this salt are found in America, whence whole ship-loads of it are exported, under the name of *Chili saltpetre;* and it is substituted for the more costly nitre in the manufacture of nitric acid and some of its salts. But it does not answer for making gunpowder, as the powder thus prepared becomes moist, and detonates too slowly.

Fig. 122.



225. *Biborate of Soda* (*Borax*) ($NaO, 2BO_3 + 10HO$).

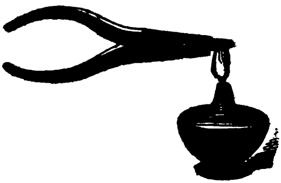
The hard, colourless crystals commonly called borax, and generally covered with an efflorescent powder, consist of soda and boracic acid. Boracic acid, in the moist condition, is a feeble acid; therefore, like carbonic acid, it cannot entirely conceal the basic properties of soda; and borax has an alkaline taste, and colours red test-paper blue. Borax contains half its weight of water of crystallisation.

Experiment.—Heat some powdered borax upon a platinum wire before the blow-pipe; it will puff up and swell in its water of crystallisation, and be converted into a porous spongy mass; on being further heated, it fuses to a transparent *bead*. Moisten this bead with the tongue, apply it to litharge so that some of the latter may adhere to it, and again hold it in the exterior flame of the blow-pipe; the litharge is dissolved; the bead remains colourless and transparent. If you now substitute for the litharge other metallic oxides, you will likewise observe that the oxides will dissolve, but that at the same time the bead will be coloured by them; namely, *yellowish-red*, by sesquioxide of iron and oxide of antimony; *green*, by the oxides of copper and chromium; *blue*, by oxide of cobalt; *violet*, by a small portion of oxide of manganese; and *brownish-black*, by an excess of manganese. The metallic oxides comport themselves also in the same manner, when they are fused into common glass or earthenware. They are for this reason called *vitrifiable pigments* (borates or silicates of metallic oxides).

On account of this property which borax has of dissolving metallic oxides, it is used in chemistry as a blow-pipe test for the *detection* of metallic oxides, and in the trades for *soldering*, or joining one metal with another.

Hold by the pincers a piece of copper, on which is placed a piece of tin and iron wire, over the flame of a spirit-lamp; the tin will indeed melt, but it will not adhere either to the copper or the iron. Repeat the experiment, having previously smeared the copper and the wire with a paste made of borax-powder and water; the result is now quite different, for the melting tin unites with both metals, and the wire, when cold, is found to be firmly soldered to the copper. The explanation of this different result is simply as follows. Metals only adhere to metals when they have clean, polished surfaces; the clean surface is lost on heating the metals, because a layer of oxide is formed upon them by the oxygen of the air; but the bright surface is restored

Fig. 123.



again by the borax, which, when it melts, dissolves the oxide formed.

Borax occurs native (tincal) in many of the lakes of Asia; but it is now prepared also from boracic acid, which is obtained from some hot springs in Italy, and is neutralised by soda.

226. *Glass* (*Silicic Acid combined with Bases*).

As boracic acid forms with soda, when heated, a *vitreous* compound, so silicic acid, which is very analogous to boracic acid, forms likewise a vitreous combination with soda, and also with other bases, as with potassa, lime, oxide of lead, oxide of iron, &c. *Glass*, glazing, enamel, &c., are varieties of this combination.

Experiment.—Melt some carbonate of potassa or soda upon a platinum wire before the blow-pipe, and then add a little finely pulverised sand; upon placing it again in the blow-pipe flame, effervescence will ensue, and afterwards a clear bead will be formed. If the proportion of sand used be *small*, the glass formed (basic silicate of potassa or soda) will dissolve in water on long-continued boiling; it is then called *soluble glass*. (§ 204.) If *more* sand is taken, a glass (acid silicate of potassa or soda) is obtained which it is very difficult to dissolve in water. To make a glass which shall be entirely insoluble, not only in water but also in acids, beside the potassa and soda, some other earth or metallic base—for instance, lime or litharge—must be added. Common glass is thus manufactured in glass-houses.

The materials which are chiefly employed in the manufacture of glass are,—*a*) quartz, flint, or sand; *b*) carbonate of potassa or wood-ashes; *c*) carbonate of soda or Glauber salts; *d*) lime or chalk; *e*) litharge or minium. These substances, after being pulverised, are mixed together, thrown into earthen pots, and heated in a furnace until the mass forms a uniform fluid. In this state it may be moulded like wax, cut and bent, pressed into moulds, and blown, and may accordingly be manufactured into all possible shapes and forms; on cooling, it becomes hard and brittle. In order to diminish in a measure the brittleness, the glass must be cooled very slowly (*annealed*). Glass vessels that are rapidly cooled often crack when they are carried from a warm into a cold room; this defect may, to a certain degree, be corrected, by gradually heating the vessels in water till it boils, and then allowing it to cool very slowly.

For colouring and painting glass the vitrifiable pigments, as noticed in § 225, are employed. The milk-white colour which we observe in the opaque glass of the lamp-screens, and in the enamel of the dial-plate of watches, is produced by finely ground bone-earth or oxide of tin, neither of which substances is dissolved by the vitreous mass, but only mixes with it mechanically, and renders it opaque, as chalk does water. Glass is ground by sand and emery, polished by sesquioxide of iron and tripoli, etched by hydrofluoric acid, and very easily perforated by the point of a three-cornered file, which should be frequently moistened with oil of turpentine.

The two principal kinds of glass are,—

a) Crown or Bohemian glass, consisting of potassa (soda), lime, and silica.

b) Flint or crystal glass, consisting of potassa, oxide of lead, and silica,

Common *bottle-glass* contains the same ingredients as crown glass, with the addition of sesquioxide of iron, which imparts to it a brownish-yellow colour, or of protoxide of iron, which gives it a green tinge. This iron is contained in the impure materials (yellow sand and wood-ashes) used in the preparation of the ordinary sorts of glass.

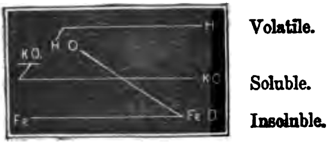
SYSTEMATIC ARRANGEMENT OF THE COMPOUNDS OF POTASSIUM AND SODIUM.

Metals:	Potassium.	Sodium.
Oxides:	Oxide of potassium, or caustic potassa.	Oxide of sodium, or caustic soda.
Sulphurets:	Sulphuret of potassium, or liver of sulphur.	Sulphuret of sodium.
Haloid Salts:	Chloride of potassium.	Chloride of sodium.
	Iodide of potassium.	Iodide of sodium.
Oxy-salts:	Carbonate of potassa.	Carbonate of soda.
	Bicarbonate of potassa.	Bicarbonate of soda.
	Chlorate of potassa.	
	Nitrate of potassa, or saltpetre.	Nitrate of soda, or Chili saltpetre.
	Sulphate of potassa.	Sulphate of soda, or Glauber salts.
	Bisulphate of potassa.	Bisulphate of soda.
		Sulphite of soda.
		Phosphate of soda.
	Silicate of potassa, or glass.	Silicate of soda, or glass.
	Basic silicate of potassa, or soluble glass.	Biborate of soda, or borax.
	Tartrate of potassa.	
	Bitartrate of potassa, or tartar.	
	Double salts of tartar.	
	Binoxalate of potassa, or salt of sorrel.	
	Acetate of potassa, &c.	

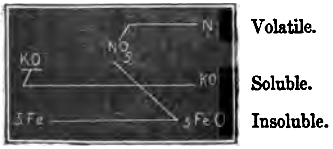
AMMONIA (NH_3).

At. Wt. = 17.—Sp. Gr. [as gas] = 0.6.

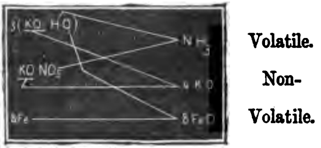
227. *Experiment.*—1.) Mix intimately together forty grains of fine iron filings, and two grains of hydrate of potassa (caustic potassa), and heat them in a test-tube, to which is adapted a bent glass tube. (Fig 26.) As soon as the atmospheric air is expelled, receive the gas as it is evolved in a separate flask; it may be inflamed by a lighted taper; it is *hydrogen*. It comes from the water of the hydrate of potassa, the oxygen of which combines with the iron. The potassa serves to hold fast the water, until a red heat is produced: water, by itself, could have been heated only to 212° F. (100° C.)



Experiment.—2.) Heat forty grains of iron filings and two grains of nitre in the same manner as before. You obtain a gas in which a lighted taper is extinguished; it is *nitrogen*. The same occurs in the case of nitric acid as with the water; the iron abstracts from it oxygen; and its second constituent, nitrogen, is thereby set free and escapes.



Experiment.—3.) Unite the two former experiments into one, that is, heat eighty grains of iron filings at the same time with two grains of potassa and two grains of nitre, in an open test-tube: neither hydrogen nor nitrogen is evolved, but a combination of both in a gaseous form, having a pungent odour resembling that of ammonia. A strip of moistened red test-paper held over the test-tube is turned blue; consequently, this new kind of gas possesses an alkaline character; we call it *ammonia*. Ammonia is, as we see, a chemical combina-



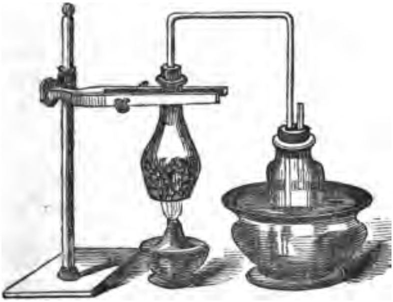
tion of *hydrogen* and *nitrogen*. But these bodies unite with each other only at the moment of being liberated from another combination (*nascent state*). If they do not come together till afterwards, when they have already become gaseous, no union takes place.

In ammonia, one atom of nitrogen is always combined with three atoms of hydrogen; therefore its formula is $N\ H_3$. From three measures of hydrogen and one measure of nitrogen are formed, not four measures, but only two measures, of ammoniacal gas; accordingly, the ammoniacal gas occupies only half the space previously occupied by its constituents, and a condensation of one-half is produced by chemical combination. In the formation of water from its constituents, this condensation amounted to two-thirds. (§ 87.)

228. *Ammonia by dry Distillation.*—Ammonia is also produced when animal substances are heated with exclusion of air. These substances always contain nitrogen and hydrogen, which, at the moment of being set free by heat, combine with each other, forming ammonia.

Experiment.—Reduce to a coarse powder one ounce of bones, and heat them in a flask as long as any volatile matter continues to escape. The flask must be previously connected, by a bent glass tube, with a bottle containing a little water, which bottle must be kept cool in a basin of water. Adapt to the cork of the receiving bottle another glass tube open at both ends, through which those gases may escape which are not absorbed by the water. These smell very disagreeably,

Fig. 124.



but the odour vanishes when they are inflamed. The gases burn with a luminous flame, like coal-gas, which they much resemble in their constitution. A brownish-black *tarry* matter is deposited in the bottle, which is known under the name of oil of hartshorn, or Dippel's animal oil. After the completion of the dry distillation, it is separated from the *watery solution* by filtering through paper previously moistened with water. The filtrate still contains some of this oil in solution, and has thereby a brown colour and an agreeable odour. But at the same time we perceive also a pungent smell of *ammonia*, which latter is also detected by means of red test-paper, the colour of which is changed to blue.

Add some lime-water to this ammoniacal solution; it becomes turbid, and emits a more powerful odour of ammonia. The turbidness is owing to the precipitation of carbonate of lime, the ammonia not being free in the liquid, but combined with carbonic acid. Carbonic acid is generated during every combustion or charring of organic substances; it here finds a base in the ammonia, and consequently combines with it. In the carbonate of potassa and carbonate of soda, we have already seen that the basic properties of the potassa and of the soda are not entirely concealed by the carbonic acid,—that the base, as it were, still glimmers through. Ammonia also comports itself exactly in the same manner; although chemically combined with carbonic acid, it still emits a pungent odour, and affords an alkaline or basic reaction. Formerly this pungent brown liquid was used as a popular sudorific, and was called *spirit of hartshorn*, because it was prepared from harts' horns, instead of from bones. For the same reason, the impure dry *carbonate of ammonia* prepared from it received the name, still in use, of *salt of hartshorn.*

It is only with difficulty that this pungent oil can be separated from the carbonate of ammonia; this separation is most easily effected by converting the carbonate of ammonia into chloride of ammonium.

Sal Ammoniac, or Muriate of Ammonia ($N H_3$, $H Cl$).

229. *Experiment.*—Neutralise the ammoniacal liquid obtained in the last experiment with muriatic acid; boil it with some animal charcoal, and filter it. After filtration, the liquid has less colour than before, because a great part of the colour-

ing matter has been absorbed by the charcoal (§ 105); after sufficient evaporation it yields brown crystals, which are finally rendered entirely colourless by repeated solution and boiling with charcoal. This salt was formerly prepared in the district of Ammonia, in Africa, from camel's dung; hence its name, *sal ammoniac*. The ammonia in this, as in its other salts, is so completely neutralised by the acids, that you can no longer recognise it by the smell.

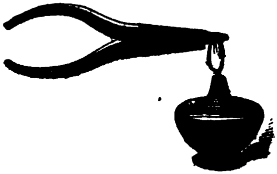
Experiments with Muriate of Ammonia.

Experiment a.—If some muriate of ammonia is heated upon platinum foil, over the flame of a spirit-lamp, it volatilises in white fumes. All ammoniacal salts are volatilised by heat. If the vapour of muriate of ammonia is condensed in a cold vessel, you obtain it as a solid, transparent mass, which is pulverised with difficulty. The sal ammoniac of commerce generally occurs in this form; it is then called *sublimed sal ammoniac.*

Experiment b.—Throw some powdered muriate of ammonia into water in which a thermometer is immersed; the powder readily dissolves, and the mercury falls considerably. In this manner, *artificial cold* may be produced.

Experiment c.—If muriate of ammonia is triturated with slaked lime or potassa, it evolves a strong *ammoniacal odour,* because the potassa or the lime abstracts from it the muriatic acid. This mixture is sometimes used for filling smelling-bottles.

Fig. 125.



Experiment d.—Put a piece of tin, the size of a pea, upon a bright halfpenny, and hold it, by means of a pair of forceps, in the flame of a spirit-lamp; when the tin is melted, rub it upon the halfpenny with a rag; it will not adhere to it. Now repeat the experiment, but strew at the same time some powdered muriate of ammonia upon the copper surface; the tin is now equally diffused by the rubbing. On this is founded the important application of sal ammoniac in tinning and soldering. The muriatic acid of the ammonia combines with the oxide of copper formed by heating, and thereby a bright surface of copper is produced, to which the fused tin will firmly adhere; hence we perceive, also, during the process of tinning, a smell of free ammonia. Ammonia and the ammoniacal salts are commonly prepared from sal ammoniac.

Ammonia, or Water of Ammonia ($NH_3 + Aq$).

230. *Experiment.*—Pour an ounce and a half of water upon a quarter of an ounce of sal ammoniac and three drachms of slaked lime, contained in a flask, arranged as described in Fig. 106, and then apply a moderate heat; the lime abstracts from the sal ammoniac, as has already been seen, its muriatic acid, and the ammoniacal gas escapes. As soon as it is released it ascends, since it is nearly one-half lighter than common air; it turns red litmus-paper blue, and forms thick white fumes of sal ammoniac when a paper moistened with muriatic acid is held in it. If the longer limb of the tube is now passed nearly to the bottom of a phial containing one ounce of water, the gas is dissolved, and you obtain a solution of ammonia (*water of ammonia*). One measure of water can absorb more than 600 measures of ammoniacal gas. Since much latent heat must therefore be liberated, the receiving vessel should be placed in cold water. A second tube, open at both ends, may be adapted to the cork of the flask to prevent the water being forced back from the phial in case the heat should accidentally be diminished. The tube must reach to the bottom of the flask, for otherwise the gas would escape through it.

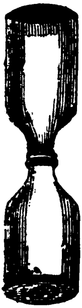
The solution of ammonia is lighter than water, and so much the lighter in proportion to the amount of ammoniacal gas it contains; for this reason, its strength may be very accurately determined by its specific gravity. Its most important properties have already been mentioned. On account of its corrosive properties it is also called *caustic ammonia.*

231. *Hydrosulphuret of Ammonia, or Sulphuret of Ammonium* (NH_3, HS).

Experiment.—Pass a current of sulphuretted hydrogen gas, evolved as described in § 132, into a solution of ammonia, as long as the solution continues to absorb the gas. This solution must be kept in well-closed glass bottles, because it is decomposed on exposure to the air, and becomes yellow. It is one of the most important chemical reagents, as will be shown hereafter.

232. *Carbonate of Ammonia* ($2\,N\,H_3,\ 3\,C\,O_2 + 2\,H\,O$).

Fig. 126.



The crude carbonate of ammonia has already been treated of; the pure is prepared from sal ammoniac and chalk, by sublimation.

Experiment.—Introduce a mixture of half an ounce of chalk and a quarter of an ounce of sal ammoniac into a four-ounce flask, having a thin bottom; place it in a sand-bath, and heat it over a spirit-lamp. As soon as pungent vapours are perceived, invert a somewhat larger flask over the former, and the fumes will soon condense into a white saline mass. By double elective affinity there are formed volatile *carbonate of ammonia*, which sublimes, and *chloride of calcium*, which remains behind, since it is not volatile.

Carbonate of ammonia (or, more correctly, sesquicarbonate of ammonia) is a white substance having a pungent ammoniacal odour, which gradually attracts more carbonic acid from the air, and becomes bicarbonate of ammonia. This salt is frequently used by bakers, instead of yeast, for raising gingerbread, spice-cakes, &c. (§ 519); it escapes in the heat as a gas from the dough, and renders it light and porous.

Other ammoniacal salts may easily be prepared from the carbonate of ammonia, by expelling the carbonic acid by means of a stronger one; for instance, by sulphuric, nitric, or acetic acid, &c.

233. *Ammonia from putrefying Substances.*—One other source of ammonia yet remains to be noticed. It occurs wherever organic substances are undergoing *putrefaction* and *decay*. Carbonate of ammonia is evolved from all vegetable and animal substances which contain nitrogen, when they putrefy or decay; hence the pungent odour of stables and dunghills. If you put a dish containing muriatic acid or diluted sulphuric acid in such places, the odour vanishes, and the muriatic acid is gradually converted into muriate of ammonia, and the sulphuric acid into sulphate of ammonia. Thus we possess in the acids a simple and cheap means of purifying the air in such places. Putrid urine contains so much carbonate of ammonia, that it is used

instead of soap-water for washing wool, and indeed even for the preparation of muriate of ammonia itself.

234. When we reflect upon the action of the animal substances already treated of, we cannot but be surprised to find how very much the *nitrogen* contained in them varies in its affinity for other elements.

The nitrogen of organic substances combines,—

With hydrogen, at common temperatures, forming ammonia (decay).

With oxygen, at common temperatures, and in the presence of a strong base, forming nitric acid in nitre beds.

With hydrogen, on the application of heat and without access of air, forming ammonia (dry distillation).

With carbon, on the application of heat, without access of air, and in the presence of a strong anhydrous base, forming cyanogen.

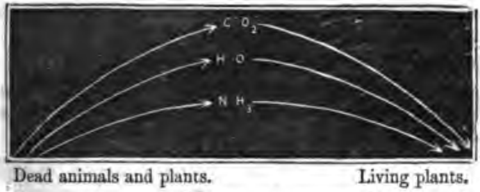
With hydrogen, on the application of heat, without access of air, and in the presence of a hydrated base, forming ammonia.

But it escapes uncombined, on the application of heat, with free access of air (perfect combustion).

235. *The Salts of Ammonia afford an excellent manure for soils.* They are the principal ingredients in many kinds of manure; and therefore we should endeavour to prevent the escape of ammonia from manure-heaps, by sprinkling them from time to time with diluted sulphuric acid, or by strewing gypsum over them, whereby sulphate of ammonia is formed, which does not volatilise at common temperatures. When bones decay, carbonate of ammonia is likewise produced from the gelatine, and to this is to be ascribed the second beneficial influence which pulverised bones exercise upon the growth of our cultivated plants. (§ 176.) Those plants which grow wild can only take up as much ammonia as they find in the air; but by manuring we give a much larger quantity of it to cultivated plants; and thus is in part explained the far greater fertility of manured soil in comparison with that which is not manured.

Ammonia affords another example of the circulation in the great economy of nature, similar to that presented in the instances of carbonic acid and water, the two other principal sources of nourishment for the vegetable world; and we cannot but be astonished at the simple manner in which the Creator has connected life and death with each other. During the processes of putrefaction and decay, the dead animals and plants are converted into carbonic acid, water, and ammonia; and from these three products of decay are reproduced all the innumerable plants which cover the surface of our earth.

Fig. 127.



236. The great resemblance of ammonia to potassa and soda has long since given rise to the conjecture, that a metal might also be concealed in it, as well as in the potassa and soda. If a body—for instance, cyanogen—which comported itself exactly like a chemical element, like chlorine, could be generated from nitrogen and carbon, so also it was possible that a body might be formed from nitrogen and hydrogen which should comport itself like a metal, like potassium. Chemists have not yet succeeded in separating such a metal from ammonia or its salts; nevertheless, the opinion is maintained by many of them, that such a metal does really exist, and consists of one atom of nitrogen and four atoms of hydrogen (NH_4). They have called it *ammonium;* and, according to this view, regard hydrated ammonia ($NH_3 + HO$) as oxide of ammonium (NH_4O), muriate of ammonia ($NH_3 + HCl$) as chloride of ammonium (NH_4Cl), &c., which amounts to the same thing, since the constitution of these two bodies is not changed, whether the hydrogen is considered as belonging to the water or to the muriatic acid, or as combined with the ammonia.

A compound of one atom of nitrogen and two atoms of hydrogen (NH_2) has been called *amide.*

LITHIUM.

A very rare base, lithia or oxide of lithium, occurs in several minerals and mineral waters; it possesses properties analogous to those of potassa. Many salts of lithia impart a beautiful crimson colour to the blow-pipe flame, and to the flame of burning alcohol.

RETROSPECT OF THE ALKALIES (POTASSA, SODA, AND AMMONIA).

1. Of all bodies, potassium and sodium have the greatest affinity for *oxygen;* they float upon water, and decompose it with great violence.

2. Their oxides are the most powerful *bases*. The oxide of potassium is commonly called potassa, or caustic potassa; the oxide of sodium, soda, or caustic soda. Ammonia must also be placed with them.

3. These three oxides are commonly called *alkalies*, also caustic alkalies. Formerly potassa was called vegetable alkali; soda, mineral alkali; and ammonia, volatile alkali.

4. The alkalies are *easily soluble* in water, have an *alkaline* taste, and exert a *strong caustic* action on animal and vegetable substances.

5. The alkalies have a very great affinity for *carbonic acid.* They absorb it eagerly from the air, and become converted into alkaline carbonates.

6. Carbonic acid *cannot* be expelled from the alkaline carbonates by heating, but it escapes immediately, with effervescence, on the addition of other acids.

7. The alkaline carbonates, carbonate of potassa, of soda, and of ammonia, are *easily soluble* in water, and have likewise an alkaline taste and a basic reaction.

8. Potassa and soda, with sand, yield melted *glass;* and with fat, a *soap*, which is soluble in water.

9. Most of the salts which the alkalies form with acids are soluble in water. Most of the potassa salts are permanent in the air, some deliquescent; most of the soda salts contain water of crystallisation, and effloresce in a dry atmosphere.

10. Potassa and soda salts are not volatile in the heat, but the salts of ammonia are so.

11. A weaker base will often remove the acid from a stronger base, when it forms with this acid an insoluble compound.

SECOND GROUP: THE ALKALINE EARTHS.

CALCIUM (Ca).

At. Wt. = 20.—Sp. Gr. 3.1.

Chalk, or Carbonate of Lime (CaO, CO_2).

237. It is already known that chalk consists of carbonate of lime; it was used, indeed, in several of the earlier experiments for the preparation of carbonic acid. We find just the same constituents also in common limestone, in marble, oyster shells, &c. There are whole ridges of mountains consisting of limestone, and extensive districts having a lime or calcareous soil; carbonate of lime is one of the principal constituents of our globe. We also find in it transparent crystalline forms, rhombohedrons, and six-sided prisms, and then call it calcareous spar. The great difference which these stones present in their exterior appearance cannot be wondered at, for we see a similar variety of form in our common sugar; we have it crystallised in sugar-candy, granular-crystalline in loaf-sugar, amorphous in bonbons, and pulverulent in pounded sugar.

Fig. 128.

All limestones *effervesce* when treated with an acid, and may thus generally be distinguished from other stones. If you smear a piece of limestone in single spots with fat or some varnish-paint, and then pour upon it an acid (a weak solution of nitric acid is the best), the lime dissolves in those places only which are unprotected by the fat or paint, the greasy spots accordingly remaining raised. If a stone thus prepared is passed over with printing-ink, this will adhere only to the elevated places, and may be transferred from them to paper. This is the method used for engraving on stone, and the limestones used in this kind of engraving are called *lithographic stones.*

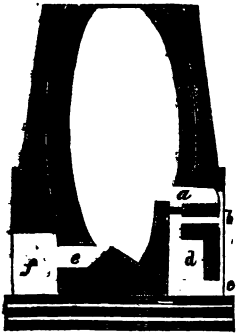
Experiment.—Blow into lime-water, through a glass tube; a precipitate of carbonate of lime is formed (see Fig. 81); continue the blowing, and the precipitate will, for the most part, dissolve again. The carbonic acid first precipitates the lime, then it dissolves it again. Carbonate of lime is quite insoluble in water, but is soluble in water impregnated with carbonic acid. Let half of the liquid remain exposed to the air, it will gradually become turbid, and carbonate of lime will be deposited; boil the other half in a test-tube, bubbles of carbonic acid will escape, and carbonate of lime will be *rapidly* precipitated. What here happens on a small scale frequently occurs in nature on a large scale. The water, as it trickles through the earth in those places where the decay of organic matter is going on, finds carbonic acid; therefore almost all spring-water contains carbonic acid. The carbonic acid water so formed finds in almost all earths and stones carbonate of lime, some of which it dissolves; therefore almost all spring-water contains carbonate of lime (*hard* water). When this water flows along in brooks, the carbonic acid escapes again, and the carbonate of lime is deposited as sediment; this water, free from lime, is now called *soft* water. The same thing happens when water containing lime, as it percolates through the earth or fissures in rocks, meets with hollows and caverns; here the carbonate of lime frequently deposits itself in solid masses, called *stalactites*. The walls of cellars and bridges are sometimes found covered with an incrustation of *stalactites*. The *calcareous tufa* deposited from the Carlsbad waters also consists principally of carbonate of lime. If you boil hard water, carbonate of lime is also precipitated; this happens especially when large quantities of it are evaporated, as in steam-boilers. Peas and beans, boiled in hard water, become incrusted with a thin coating of lime, which prevents the water from penetrating, so that they do not become soft; for such purposes, the water should previously be boiled, or exposed for some time to the air.

Caustic Lime, or Quicklime (*Oxide of Calcium*, Ca O).

238. *Experiment.*—Put a piece of chalk upon charcoal, and heat it strongly before the blow-pipe for several minutes; it will then become much lighter than before, and will no longer effervesce with acids; it has by the heating lost its carbonic acid, and is now called *burnt lime*. If a portion of it is placed on moistened red litmus-paper, it causes blue spots; consequently it has a *basic* reaction, which chalk has not.

For burning large masses of chalk or limestone, kilns of the annexed form are constructed. *a* is the fire-door, with the grate, upon which coal or turf is burnt; *b*, the opening for the

Fig. 129.



draught of air; *c* and *d*, the ash-pit. In this, as in the reverberatory furnace, the flame only enters the shaft of the kiln, which is filled with limestone; consequently the lime cannot be rendered impure by the ashes of the fuel. A kiln is usually provided with several such furnaces. *e* and *f* are the discharge outlets for extracting the lime when it is well calcined, fresh carbonate of lime being introduced at the top as the burnt lime is removed. Such furnaces may be kept at work for years without interruption.

Quicklime has two strong affinities, namely, for *water* and for *carbonic acid*. On exposure to the air it first attracts water, and thereby crumbles into powder,—it is slaked; afterwards it absorbs also carbonic acid, when it again effervesces with acids. The rapid slaking of lime when sprinkled with water, and the consequent evolution of heat, have been previously treated of. (§ 33.) Three pounds of lime combine with one pound of water, forming a fine powder of *hydrate of lime* ($Ca\,O + H\,O$), or slaked lime. When mixed with water into a paste, it forms a calcareous paste; if more water is added, it becomes milk of lime, and when mixed with 600 times its quantity of water, a clear solution, lime-water, is obtained. Like Glauber salts, it is much more soluble in cold than in hot water, the latter dissolving only half as much as the former. On account of the great affinity of burnt lime for water, it may be employed for drying damp places, and for preparing anhydrous or absolute alcohol from the common alcohol.

Examples of the avidity with which quicklime combines with carbonic acid have already been given, under combustion, and in the preparation of caustic potassa and of caustic soda. Hence it is very useful for purifying air which contains much carbonic acid; for instance, the air in old cellars, wells, mines, or in cellars in which fermenting liquors, as wine, beer, brandy, mash, &c., are kept. Milk of lime is also commonly used for abstracting from crude illuminating gas its carbonic acid, as well as the admixture of sulphuretted hydrogen. It is likewise in general use for whitewashing; it becomes quickly white and dry, and then it is no longer hydrate of lime, but chalk.

239. *Lime as Mortar.*—Glue is used for joining together pieces of wood; and *mortar*, a mixture of lime and sand, for cementing together stones. This is the most important application of lime. A mixture of lime and sand, on exposure to the air, gradually forms into a hard and stony mass. This consolidation is to be ascribed to three causes;—1st, the water evaporates, and the hydrate of lime remains behind as a cohesive mass; 2nd, the lime attracts carbonic acid from the air, and there is formed a mixture of hydrate of lime and carbonate of lime, which possesses greater firmness than either body separately; 3rd, on the surface of the sand a chemical combination is gradually formed of the silicic acid with the lime, both becoming, as it were, incorporated together. This explains the remarkable hardness of the mortar in old buildings. When our structures of the present day shall have stood for centuries, the mortar about them will certainly possess the same degree of firmness, provided good quartz sand has been employed in its preparation, and not the argillaceous sand so often used. Sand also diminishes the shrinking or contraction of the mortar, and prevents its cracking as it becomes dry. Old mortar accordingly consists of hydrate of lime, carbonate of lime, silicate of lime, and silica (sand).

If you burn a limestone in which clay is contained, or an intimate mixture of chalk with one-fifth of clay, you will obtain a burnt lime, which, when mixed with water and sand, yields a mortar that hardens quickly, like plaster of Paris, and becomes as hard as stone under water; it is called *hydraulic cement*, and is well adapted for building piers of bridges, or other structures under water. Clay is silicate of alumina; therefore hydraulic cement is an intimate mixture of quicklime with silicate of alumina.

240. *Further Experiments with Lime.*

Experiment.—Wrap a piece of quicklime in paper or in a linen rag, and set it aside for some weeks; the paper and the linen will become, after a time, so rotten as to be easily torn; the lime, to use a common expression, has eaten them. Thus quicklime, like potassa or soda, exerts a corrosive action upon organic substances, and for this reason it is also frequently called *caustic lime.* If you rub between the fingers lime made into a paste with water, you readily perceive by the feeling its caustic action upon the skin. In tanneries, the hides are immersed in milk of lime, in order to loosen them, so that the hair may easily be rubbed off; and in agriculture, lime is mixed with weeds, such as couch-grass, &c., to accelerate their decomposition. It is, however, altogether wrong to mix lime with manure that is already in a state of decay and putrefaction, because it contains ammoniacal salts, the ammonia of which would be set free by the lime, and escape; the manure would thus lose much of its efficacy.

Many plants, as peas, clover, and tobacco, flourish only in a soil containing lime. If you burn such plants, you always obtain, let them grow wherever they will, ashes which contain more than half their weight of lime salts; we call such plants *lime plants*, and must conclude from these two facts, that lime is as indispensable for the life of many plants, as common salt is for that of animals. Thus agriculturists possess in lime an excellent manure for those fields where lime is deficient.

Experiment.—Dissolve a little soap in hot water, and add lime-water to it; the solution becomes turbid, and afterwards white flakes are deposited, which feel sticky when rubbed between the fingers. The same thing is observed on washing with soap and lime-water; the soap neither lathers nor cleanses. Therefore, water containing lime, the so-called hard water, cannot be used for washing. The viscous mass which separates is lime soap, a combination of the fatty substances contained in the soap with lime. Potassa and soda soap are soluble in water, lime soap is insoluble.

Caustic lime is a combination of oxygen with a metal, which has received the name *calcium* (Ca); it may therefore be called, also, oxide of calcium (Ca O). Lime is, next to the alkalies, one of the strongest bases.

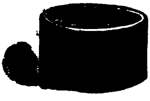
Sulphate of Lime, Gypsum ($Ca\,O, S\,O_3 + 2\,H\,O$).

241. *Experiment.*—Expose to a moderate heat in an iron vessel the sulphate of lime obtained in former experiments (§§ 164, 176), stirring it during the heating, which must be continued till vapours cease to escape from it; it will afterwards weigh one-fifth less than before, and then forms *calcined sulphate of lime*, and is the same as plaster of Paris. The loss of weight is owing to the water of crystallisation which was

driven off by the heat. A temperature of 248° F. (120° C.) is sufficient to effect this.

Experiment.—Wind round the rim of a half-crown, a strip of paper, firmly securing the loose end of it by sealing-wax. A box is thus made, the bottom of which is formed by the coin, Now mix two even spoonfuls of sulphate of lime and a spoonful of water into a paste, stir it round quickly, and pour the paste into the box; after a few minutes it will become so hard that both the paper and the coin can be removed. A reversed impression of the coin will appear on the under side of the plaster. After this is perfectly dry, smear the impression with a strong solution of soap, mixed with a few drops of oil, and upon pouring over it some of the sulphate of lime paste, a true stamp of the coin will be obtained. The rapid hardening may be thus explained: the anhydrous burnt sulphate of lime again chemically combines with as much water as it has lost during the ignition. If it had been heated above 320° F. (160° C.), it would not have hardened; it having then lost its affinity for water. In a similar manner, figures of plaster of Paris are made in hollow moulds. Plaster of Paris is used in architecture for making on walls and ceilings various ornamental figures and designs, called stucco-work.

Fig. 180.



Sulphate of lime (gypsum) is a mineral of very frequent occurrence in nature, and in some localities, as at Jena, it forms entire ranges of hills. It also occurs abundantly near Paris, whence the name plaster of Paris. When crystallised in tables it is termed *selenite*, and the white, compact, granular variety is called *alabaster*. It is also frequently contained in spring-water.

Gypsum is very sparingly *soluble* in water; half an ounce of the latter dissolving only half a grain of gypsum.

To detect sulphate of lime in a liquid add to one portion a solution of chloride of barium, whereby the presence of sulphuric acid is indicated; and, to another portion, a solution of oxalic acid, by which the presence of lime is shown. Oxalic acid is the most certain test for lime salts. (§ 197.)

That gypsum, as well as quicklime, is a valuable manure for many plants, especially for the leguminous plants, is well known to farmers, who frequently spread it over their clover fields. The plants hereby not only absorb the lime but also the sulphur of the sulphuric acid. Gypsum has also a beneficial effect on the growth of plants, as it absorbs the carbonate of ammonia contained in the air and in rain-water, and fixes it in the soil, these two salts being converted respectively into sulphate of ammonia and carbonate of lime.

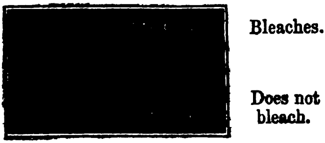
When gypsum is heated to redness with charcoal, *sulphuret of calcium* is obtained, which, like the liver of sulphur, evolves sulphuretted hydrogen, when drenched with diluted acid.

242. *Phosphate of lime* constitutes, as already mentioned, the principal ingredient of *bones;* it occurs in the mineral kingdom as apatite and phosphorite.

243. *Nitrate of lime* ($Ca\,O, N\,O_5$) is always formed when azotised substances and lime remain for some time together in contact. (§ 207.) This salt is very often generated in the plaster of walls, in those buildings where urinous liquids or ammoniacal fumes are present, as in stables. The lime loses hereby its adhesiveness, and crumbles, especially when the rain washes out the easily soluble nitrate of lime. This process is commonly known as the crumbling away of the walls.

Chloride of Lime, or Hypochlorite of Lime ($Ca\,O, Cl\,O + Ca\,Cl$).

244. *Experiment.*—Mix half an ounce of slaked lime with six ounces of water, and conduct into this milk of lime, with frequent agitation, as much chlorine as will evolve from two ounces of muriatic acid and half an ounce of black oxide of manganese. The liquid, clarified by standing, may be regarded as a solution of *chloride of lime,* and must be kept protected from the air and light. It would seem at first as if the chlorine united directly with the lime, but this is not possible, since, as a general rule, simple bodies cannot combine with compound bodies. The process is as follows. Half of the lime releases its oxygen, and is converted into calcium, which, being a simple body, combines with chlorine; the oxygen, liberated from the lime, combines with the rest of the chlorine, forming hypochlorous acid ($Cl\,O$), which, being a compound body, can now unite with the other half of the lime. Thus are formed a haloid salt, chloride of calcium, and an oxygen salt, *hypochlorite of lime.* The latter is the essential agent, the bleaching power, in the chloride of lime;



chloride of calcium is to be regarded only as an unnecessary make-weight. Accordingly, the name of chloride of lime is incorrect, but, like many other terms of general acceptation, it would be inconvenient not to retain it. It must not be forgotten, however, that *chloride of lime* is a very different body from *chloride of calcium.*

By the old process, bleaching required weeks, and even months; now, by means of chloride of lime, cotton and linen are bleached in as many days. For this reason, vast quantities of chloride of lime are manufactured in chemical manufactories, and are consumed in bleacheries and calico print-works. The preparation of it on a large scale is conducted upon the same principle as that just described, except that, instead of milk of lime, slaked lime is used, which is spread upon hurdles in chambers, and which, like milk of lime, absorbs the chlorine. Chloride of lime, thus prepared, is a granular powder, which absorbs moisture from the air, and emits the odour of chlorine. Upon adding water to it, the same liquid is obtained as that prepared above.

245. *Experiments with Chlorine.*

Experiment a.—Immerse a piece of cotton, printed with various colours, into a solution of chloride of lime; if there are vegetable colours among those with which the cotton is printed, they will bleach, though but *slowly.*

Experiment b.—Proceed in the same manner, adding, however, to the solution some drops of diluted muriatic or sulphuric acid; the bleaching will then take place *instantaneously*, attended with the evolution of a strong smell of chlorine. The acids expel the feeble, hypochlorous acid, and this is resolved into oxygen and chlorine. If you let the material remain for some time in the solution of the chloride of lime, the vegetable fibres will also be decomposed (*eaten*) by the chlorine, and will lose their firmness.

Experiment c.—Drop some tincture of indigo into a portion of the solution; the indigo is immediately decomposed, and its blue colour changed to yellow. Continue to add the indigo till the blue colour remains unaffected, and note the quantity of indigo used; in this manner the strength of the different sorts of chloride of lime may be determined, for the more hypochlorous acid there is contained in the chloride of lime, so much the more indigo it is able to deprive of its colour.

Experiment d.—Chloride of lime, as well as free chlorine, destroys the *noxious effluvia* evolved during the decay or putrefaction of organic substances. The impure air of stables is destroyed by strewing about chloride of lime, and damp cellars are purified by washing the floors and walls with a solution of it, &c.

In all these decompositions, the chlorine always combines with the *hydrogen* of the colouring and odorous matter.

If chlorine is conducted into a solution of carbonate of soda, instead of into milk of lime, we obtain *hypochlorite of soda*, likewise a bleaching liquid, known as *Labarraque's disinfecting liquor.*

Chloride of Calcium, or Muriate of Lime (Ca Cl, or Ca O, H Cl).

246. *Experiment.*—Mix muriatic acid with half its quantity of water, and add to it pieces of chalk until effervescence ceases; then evaporate the filtered solution to the consistency of a syrup. We obtain from this, on cooling, large prysmatic crystals of chloride of calcium, which must be quickly dried by pressure between folds of blotting-paper, and kept carefully excluded from the air, as they are exceedingly deliquescent. In the winter season, this salt may be employed for freezing mercury. For this purpose let it remain one night in a cold place, then grind it up in a cold mortar, and mix it with snow; if some mercury, contained in a glass tube, is now introduced into the mixture, it will become solid, and a spirit-of-wine thermometer will indicate a temperature of —40° F. (—40° C.) The snow and the chloride of calcium melt; from two solid bodies is thus formed a liquid, and during this transition a great quantity of free heat must necessarily become latent.

Crystals of chloride of calcium contain half their weight of water of crystallisation; on being heated, the water passes off, and we obtain *fused chloride of calcium*, one of the *most hygroscopic* salts, which may be employed for preparing absolute from common alcohol, and for drying certain gases. For this latter purpose, fill a capacious glass tube with fragments of it, and adapt to each end of the tube, by means of perforated corks, two small glass tubes, through which the gas

Fig. 131.

may be transmitted; during its passage, all the moisture will be abstracted from it by the chloride of calcium. In the preparation of ammonia (§ 230), chloride of calcium is obtained as a secondary product. It has already been mentioned (§ 244), that it forms a constituent (though a useless one) of chloride of lime.

247. *Fluoride of Calcium* (Ca Fl), commonly called *fluor-spar*, is a mineral of frequent occurrence in nature, and is often found in cubic crystals of great beauty. It is easily fused by heat (hence its name), and it yields, when treated with sulphuric acid, hydrofluoric acid. (§ 190.)

BARIUM AND STRONTIUM (Ba and Sr).

At. Wt. = 69.—At. Wt. = 44.

248. These two metals have so great a similarity to calcium in their properties and combinations, that they may be regarded as brethren. Their oxides are termed baryta (Ba O) and strontia (Sr O), and when water is added to them they evolve heat, as is the case with lime, and afford a *basic* reaction. The carbonates of baryta and strontia are, like chalk, *insoluble* in water, and at a strong heat lose their carbonic acid, yet not so readily as chalk. The salts of lime, as has been seen, are very easily prepared by merely adding acids to marble or chalk; but the salts of baryta and strontia are not so easily obtained, because baryta and strontia are rarely found in nature combined with carbonic, but most frequently with sulphuric acid—consequently, with an acid which is stronger than all others. It is therefore necessary, as in the preparation of soda, to adopt a circuitous method. It must first be reduced to a sulphuret by heating with charcoal; this sulphuret may be afterwards decomposed by acids.

Chloride of barium, or muriate of baryta (Ba Cl), is the most common soluble salt of baryta. It crystallises in transparent tables, and is used in medicine. The chemist also makes use of it as the surest test for sulphuric acid and the sulphates. (§ 171.) Nitrate of baryta serves also for the same purpose.

Sulphate of Baryta (Ba O, S O_3).

Experiment.—Dissolve some Glauber salts in water, and add

Soluble.

Insoluble.

a solution of chloride of barium, as long as any precipitate is produced. Chloride of sodium and sulphate of baryta are formed by double elective affinity. The latter is quite insoluble in water, and also in acids, and is therefore thrown down as a heavy white powder. The ponderous mineral known as *heavy spar*, which is frequently found in beautiful tabular crystals, associated particularly with metallic ores, is the native sulphate of baryta. Baryta and the baryta salts are prepared from it. This mineral, when ground to powder, is frequently used for the adulteration of white-lead.

The most remarkable characteristic of the *strontia salts* is that of communicating a *crimson tint* to the flame of burning substances. *Nitrate of strontia*, like the other nitrates, deflagrates upon burning charcoal, and is used for producing a crimson flame in fireworks, prepared from potassa, sulphur, and charcoal. *Chloride of strontium*, or muriate of strontia, is soluble in alcohol, and imparts to its flame a crimson colour.

MAGNESIUM (Mg).

At. Wt. = 12.—Sp. Gr. = 1.7.

Epsom Salt, or Sulphate of Magnesia

($Mg\ O,\ S\ O_3 + 7\ H\ O$).

249. Envelop in a fold of strong paper a fragment of serpentine mineral. Crush it with a hammer; then pulverise it in an iron mortar, and mix half an ounce of it in a porcelain basin with some common sulphuric acid to the consistency of a paste, and set it aside for some days in a warm place. Then stir in carefully an ounce and a half of water, let the mixture stand again for some days, and finally decant the warm clear liquid. It will have a green tint, owing to the presence of some protoxide of iron. When boiling, add gradually nitric acid to it, until the liquid has assumed a yellow colour; the protoxide will be thereby converted into sesquioxide of iron. If evaporated until a pellicle is formed, crystals will be deposited, which must be dissolved again in boiling water, and recrystallised. Sulphate of sesquioxide of iron, which can be

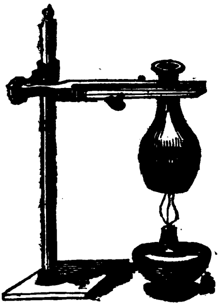
crystallised only with difficulty, will remain in the mother liquor. The crystals have a bitter taste. Their constituents are sulphuric acid and a base called magnesia (Mg O). The taste of all the soluble salts of magnesia is bitter. This base is combined in the serpentine with silicic acid, which the stronger sulphuric acid displaces and combines with, forming a soluble salt, while the silica remains behind undissolved. We find silicate of magnesia also in other minerals—for instance, in meerschaum, soap-stone, talc, asbestos, hornblende, and in several varieties resembling mica, &c. All these minerals have a slippery or greasy feeling, and are mostly included under the general head of talc. Magnesia is sometimes called also *talc earth.*

Epsom salt is one of the most common purgatives, and is much employed in medicine. We usually obtain it in commerce, not in perfect crystals, but in the form of small acicular crystals, owing to the evaporation having been carried on after the formation of the pellicle, and to the stirring of the mass while cooling. Consequently a disturbed crystallisation has taken place. In many places, for instance at Saidschütz in Bohemia, there are springs holding Epsom salt in solution, and they are often resorted to by invalids. If their waters are evaporated, this salt is likewise obtained from them.

Carbonate of Magnesia.

250. *Experiment.*—Dissolve half an ounce of Epsom salt in four ounces of cold water, and add a solution of carbonate of soda as long as a precipitate continues to fall. The precipitate is *carbonate of magnesia*, but sulphate of soda remains in the solution; thus the Epsom salt and carbonate of soda have exchanged their acids. The milky liquid is now heated to boiling, filtered, and the precipitate washed and dried; it is very light and white, and is known as the *magnesia alba* of the apothecaries' shops. During the ebullition, some carbonic acid escapes. Carbonate of magnesia is also found in many kinds of marble and limestone, called *dolomite.*

Fig. 132.



Magnesia (Oxide of Magnesium) (MgO.)

If you heat carbonate of magnesia to redness, it loses, like chalk, its carbonic acid, and at the same time the water with which it was chemically combined; the magnesia remains behind as a light powder, commonly called *calcined magnesia* (oxide of magnesium). It is nearly insoluble in water, and consists of a metal, *magnesium*, and of oxygen.

Chloride of Magnesium, or Muriate of Magnesia
($MgCl$, or MgO, HCl).

251. *Experiment.*—Add to carbonate of magnesia some diluted muriatic acid; the carbonic acid escapes, but the chloride of magnesium is dissolved in the liquid. This salt is always found associated with common salt, and as it is very soluble and hygroscopic, it remains in the mother liquor on the evaporation of salt-springs. Therefore Epsom salt may also be obtained from the mother liquor, by converting chloride of magnesium into sulphate of magnesia. The bitter taste of sea-water is owing to this salt.

Experiment.—Put into a glass of water a few drops of the above solution, or a little Epsom salt, and then add to it a solution of phosphate of soda and some ammonia; the liquid first becomes turbid, and finally a crystalline precipitate is deposited (phosphate of magnesia and ammonia). In this way the presence of magnesia may be most certainly detected.

RETROSPECT OF THE ALKALINE EARTHS (LIME, BARYTA, STRONTIA, AND MAGNESIA).

1. *The metals of the alkaline earths* have, like the alkali-metals, a very great affinity for oxygen; the preparation of them is exceedingly difficult.

2. Their oxides are called *alkaline earths*;—earths, because they are sparingly soluble; alkaline, because they have a basic reaction. (The alkalies are easily soluble.)

3. The alkaline earths are, next to the alkalies, the *strongest bases.*

4. The alkaline earths have a *caustic* action, but far less than the alkalies; hence the terms *caustic lime* and *caustic baryta.*

5. They likewise eagerly absorb *carbonic acid* from the air.

6. The carbonates of the alkaline earths are *quite insoluble* in water (the carbonates of the alkalies are easily soluble).

7. The carbonates of the alkaline earths *lose their carbonic acid by exposure to a powerful heat* (the alkalies do not).

8. The alkaline earths form with fats *insoluble soap* (the alkalies soluble soap).

THIRD GROUP: METALS OF THE EARTHS.

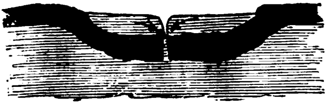
ALUMINUM (Al).

At. Wt. = 14.—Sp. Gr. 2.67.

Clay and Loam.

252. The peculiar action of clay on being mixed with water is familiar to every one, forming with it a compact, ductile mass, which may be kneaded into any shape; it is *plastic*, or may be moulded. If a mixture of lime and sand is treated in the same manner, it will not cohere, but remain friable. Common clay contains more sand than plastic clay, and, owing to the presence of iron ochre, has a yellow or brown colour. There is still a coarser variety of clay, mixed with still more sand, commonly called loam.

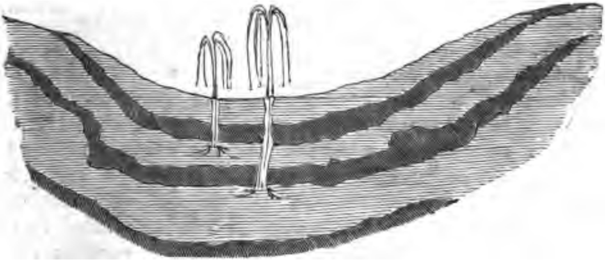
Fig. 133.



Experiment.—Hollow out a piece of clay, and pour some water into the cavity thus formed; the water will *not percolate* through the clay, as it would through sand or lime. When beds of clay exist beneath the soil, the rain is unable to penetrate far down in those places; and consequently *bogs* and *marshes* are formed. These may be drained by boring holes through the clay-beds, down to a looser layer of earth, through which the water can flow off.

There are found in many places in the interior of the earth alternate beds of clay and silica, or sand, one above the other. If these strata ascend on each side, forming hills, the rain-water, as it runs down, must collect between the layers of clay, and rise in them as in a tube, since it cannot find a vent in any direction. If, in such a geological formation, a low situation be selected for boring through the upper strata of clay, the water will be forced out above the surface of the soil, and a natural fountain will be the consequence, from which the water

Fig. 134.



will be forced still higher on boring through the second layer of clay. These fountains are called *Artesian wells*, from the province of Artois, in France, where the nature of the soil is peculiarly adapted to such works.

Experiment.—Put on a paper filter half an ounce of dry pulverised clay, and on another half an ounce of sand; pour water over each, and weigh them as soon as the filtration has ceased; the clay will weigh three-eighths of an ounce, and the sand only one-eighth of an ounce more than before. If the sand had been very coarse, its increase of weight would have been still less. Clay is, indeed, insoluble in water, but, like a sponge, it can imbibe and retain a large quantity of it; it has a very great capacity of *retaining water*. In consequence of this property, it also parts with water again much more slowly than sand does, as may be easily seen if you put both filters in a warm place to dry. These two species of earths exhibit, when dry, a still greater difference: the clay forms solid, hard lumps, the sand remains a loose, granular powder.

253. *Experiment.*—If you digest some clay in an infusion of logwood (§ 174), the clay acquires, after standing some hours, a violet colour, and the liquid becomes much more transparent. The clay has the power of *absorbing colouring matter*, and rendering it insoluble. Potters' clay, or pipe-clay, comports itself in the same manner towards unctuous substances, and hence it is much used for extracting grease-spots from wood, paper, &c., by spreading it over their surface, and letting it remain one or more days in contact with them. A soft variety

of clay is employed in cloth factories, under the name of *fuller's earth*, for removing again the grease applied to the wool in spinning.

254. *Experiment.* — Expose half an ounce of thoroughly dried clay to the air for some weeks, when it will be found to have gained in weight. This increase of weight can only proceed from the substances which it has absorbed from the air; these are water, carbonic acid, and ammonia. Of the presence of the ammonia you may easily be convinced by the smell, or if you triturate a piece of clay taken from an old wall, in the vicinity of barns especially, with some lime and a few drops of water. Clay, when freshly dug, diffuses no odour of ammonia, or only a very slight odour, on being treated in the same manner. Thus is explained, also, the peculiar smell which you perceive in all argillaceous stones when you breathe upon them, and by which you can readily determine whether clay is contained in an earth or stone. As water, carbonic acid, and ammonia are the most important means of nourishment for plants, it is very obvious that clay must enhance the fertility of the soil, because it attracts those substances from the air. That clay is especially efficacious which has remained for years in contact with the air, since in consequence of slow weathering, soluble salts of lime and potassa (nitre, &c.) have formed in it.

For this reason, bricks, or clay fragments of old buildings, are valued by the experienced farmer as excellent manure. Clay, when gently burnt, also experiences a similar change. (§ 258.)

Constituents of the Soil.

255. *Clay, or loam, and sand form the principal ingredients of our soil;* therefore, the knowledge of their properties is of great importance to the agriculturalist, since it enables him to form a judgment as to the different action of soils in wet or dry, in cold or hot weather, &c. A soil wholly composed either of sand or of clay is totally unproductive; but a mixture of them affords a fertile soil. A clayey or *fat* soil is too compact and heavy, not allowing the roots, of the smaller plants particularly, to spread sufficiently; it is likewise so dense that it will not allow of a free circulation of air. By showers of short duration it becomes *caked;* that is, a crust

forms on the surface, which prevents the water from penetrating into the soil; but after long-continued rains it becomes *muddy*, and then it allows the water to evaporate but slowly, and remains for a long time *wet and cold*. A sandy or *lean* soil suffers from the opposite disadvantages; it has too little consistency and is too porous, and, therefore, does not hold firmly the roots of the plants; it is easily raised up and blown away by the wind; it permits the rain to penetrate too deeply, and afterwards to evaporate again too rapidly. These properties constitute what is called the physical or external condition of the soil. It is now evident, that the physical condition of a clayey soil may be ameliorated by the addition of sand, and that of a sandy soil by the addition of clay, loam, or marl.

256. *Testing a Soil.—Experiment.*—To ascertain the relative amount of clay and sand in a soil, triturate half an ounce of it in a mortar with some water into a uniform paste. Dilute it with more water, and pour the turbid liquid into a tall glass, rinsing out with water what remains into the mortar. On standing, the earthy particles will settle to the bottom, according to their different specific gravities, first the coarse, then the fine sand, and finally the clay or loam; and an approximative conclusion of the comparative quantity of each may be arrived at by observing the different heights of the layers of sand and clay. This estimation may be rendered more accurate by again stirring the sediment, and, after a short time, decanting it into another vessel, using the precaution, however, not to decant the sand, which, on account of its greater weight, sinks first to the bottom. The residue is again stirred up with water, and the latter decanted, and these processes continued until all the clay is washed out of the sand. While decanting, hold a rod against the rim of the glass, so that the liquid may not be lost by flowing down on the outer surface of the vessel, or else besmear the rim with tallow, which will likewise prevent the adhesion of the liquid to the glass. The sand is dried and weighed, and the loss in the original half-ounce is to be calculated as clay.

Fig. 135.

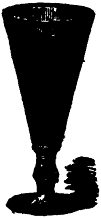
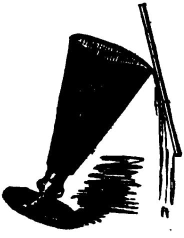


Fig. 136.

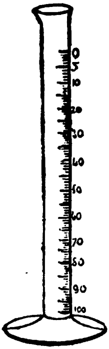


This operation, by which light bodies are mechanically separated from heavier ones, is called *elutriation*. It is frequently employed to separate finely-crushed ores from the admixture of the lighter particles of stone and earth.

The third very important ingredient of soils is *lime* (§ 237), which may be estimated in the following manner.

Experiment.—Put into a capacious flask half an ounce of well-dried soil; pour over it three ounces of water, and then add gradually half an ounce of muriatic acid, and let it remain for some hours in a warm place. When the effervescence has ceased, pour the liquid upon a filter, and wash the flask and filter with some ounces of warm water. Add ammonia to the yellowish filtrate till it has a decided smell of it; the brown flaky precipitate which is hereby separated consists of hydrated oxide of iron and alumina, which you must remove by a second filtration. The clear solution obtained is then boiled in a flask, and a concentrated solution of carbonate of ammonia or carbonate of potassa is added, as long as any precipitate forms. This is carbonate of lime, which you must collect on a filter, wash, dry, and weigh. A more simple method is to pour the contents of the flask into a graduated glass cylinder, and determine by measure the lime, which soon settles at the bottom. You previously determine the weight of a degree of lime, once for all, by dissolving 4, 6, 8, 10, &c., grains of chalk in diluted muriatic acid, precipitating them by carbonate of ammonia, and then marking the space occupied by the precipitate in the graduated cylinder. If you have more liquid than the cylinder holds, you may either evaporate the liquid, or perform the experiment with half the quantity. This method, however, will not give very accurate results when the soil contains not only lime, but also alumina, since this is partially precipitated at the same time with the carbonate of lime.

Fig. 137.



These two simple tests, the mechanical and the chemical, deserve to be more frequently employed by the farmer than they actually are; indeed, by means of them, and without any costly apparatus or much expense of time, he can make himself sufficiently acquainted with the most important constituents of his different soils.

Earthenware.

257. The *plastic* property of clay, together with that of *hardening* by heat, render it peculiarly adapted for the manufacture of *earthenware.* The clay, having been more or less purified by elutriation and kneading, is either fashioned by the hand upon the potter's lathe, or formed by pressure in moulds into articles of various shapes; these are first dried in the air, and then baked in furnaces, until they have become hard like stone. The clay contracts in drying, but still more in baking; consequently, earthenware is smaller after being baked than before. On account of this property, small cylinders of clay were formerly used for measuring high temperatures (*Wedgewood's* pyrometer). Though earthenware acquires by baking great hardness and solidity, yet it still remains so porous as to imbibe water, and also to let it transude. This fault is remedied by covering the ware with a vitreous coating, the so-called *glazing*, which is composed of the same materials as glass. (§ 226.) The most important kinds of pottery are—

a.) Bricks and flower-pots, made of loam or coarse clay, mostly unglazed. The brownish-red colour of bricks is owing to the presence of oxide of iron.

b.) Earthenware, made of common clay, and coated with a glazing of litharge and clay.

c.) Stoneware (fine earthenware), made of very white clay, and likewise covered with a glazing of litharge and clay.

d.) Delftware, stoneware covered with a glazing, which is rendered opaque and of a milky whiteness (enamel) by oxide of tin (white Dutch tiles, &c.).

e.) Porcelain is made of the finest clay (porcelain clay or kaolin), with felspar, and baked till fusion commences; the glazing consists of potassa-glass, without litharge.

f.) English stoneware (ordinary porcelain) is made of grey clay, not strongly baked; the glazing is prepared from common salt, which is thrown into a hot pottery furnace, and consists of soda-glass without litharge (milk-pans, beer-jars, &c.).

Only the vitrifiable pigments (metallic oxides) can be employed for staining and ornamenting the different kinds of pottery.

Composition of Clay.

258. *Experiment.*—Dry thoroughly a piece of white clay, and expose it for some hours to a powerful heat, which is most easily

done on the plate of a heated oven; then rub two ounces of it to a powder in a porcelain bowl with one ounce of sulphuric acid; pour upon the mixture one ounce of water, and let it remain some weeks in a warm place. Frequently stir the mass during this time with a glass rod. Finally, dilute it with six ounces of boiling water, and strain it through linen. The residue on the latter consists principally of silicic acid, but a base called *alumina* ($Al_2\ O_3$) is found dissolved in the liquid.

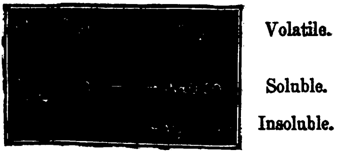
Clay is, accordingly, an insoluble salt, *silicate of alumina*. Before the clay is heated, the silicic acid holds on so firmly to the base that the sulphuric acid is not able to expel it; but it can do this after the clay has been moderately heated. All clay (and loam) contains, besides silicate of alumina, variable quantities of silicates of potassa, soda, lime, &c., which are likewise rendered dissolvable by burning the clay. To these alkalies, as well as to the greater porosity of the heated clay, it is to be attributed that a heavy clayey soil, which is impervious to the air, is converted merely by burning into very fertile soil, and that badly (slightly) burnt bricks yield a very efficient material for manure.

Sulphate of Alumina ($Al_2\ O_3,\ 3\ S\ O_3 + 18\ H\ O$).

259. *Experiment.*—Evaporate the liquid obtained in the former experiment till only one and a half or two ounces of it remain, and then put it in a cool place; it will crystallise in thin silky plates of a pearly lustre, which are very deliquescent; they consist of *sulphate of alumina*. Pour off the liquor remaining behind, which always contains free sulphuric acid, and again dissolve the crystals in a little water. In factories the solution is frequently evaporated to dryness, and a solid mass is thereby obtained, which is employed in calico-printing and dyeing.

Alumina, or Oxide of Aluminum ($Al_2\ O_3$).

260. *Experiment.*—Add a solution of carbonate of soda to half of the above solution of sulphate of alumina, until the liquid reacts basically; a brisk effervescence ensues, and a gelatinous precipitate is formed, which, after repeated washings with water, will dry in a warm place into a white powder. This powder is a combination of alumina with water, *hydrate of alumina*



(Al_2O_3, 3 H O). It is insoluble in water, and cannot combine, like the bases previously considered, with carbonic acid; hence the carbonic acid gas, set free from the carbonate of soda, escapes with effervescence. Alumina differs from clay in *not being rendered plastic* by water, and from lime, baryta, strontia, and magnesia in *not giving* an alkaline reaction.

The constituents of alumina are aluminum and oxygen—one atom of aluminum and one and a half of oxygen. Such bases are called sesquiatomic, to distinguish them from the one-atomed bases, hitherto considered as K O, Na O, Ca O, &c. The numbers of these bases are doubled, in order to avoid the inconvenience of using fractions; thus—1 : $1\frac{1}{2}$: : 2 : 3, = Al_2O_3.

Experiment.—Heat in a test-tube some alumina with potassa; it dissolves in it *completely*, since it enters into combination with the potassa. We call alumina a *base*, because it combines with acids; we may also regard it as an *acid*, for it combines also with bases. We shall hereafter find among the metallic oxides other such irresolute, double-faced characters, which play the part of a base towards strong acids, and of an acid towards strong bases. Striving to be both, they are in reality neither, and therefore salts with alumina for the base always have an acid reaction, and those with alumina as the acid a basic reaction, but both of them are very easily decomposed.

Alumina is a body of extremely *difficult fusibility;* we can only melt small quantities of it before the oxyhydrogen blowpipe. The melted alumina has the appearance of glass, and a hardness which is only surpassed by that of the diamond (artificial rubies). In this form we find alumina also in nature; the *ruby*, the most costly red precious stone, and the *sapphire*, the most costly blue stone, consist of crystallised alumina. *Emery* has also the same constitution, and is employed, on account of its hardness, for polishing metals and glass.

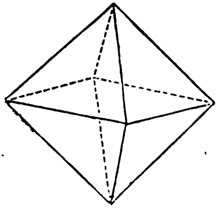
Alum (Sulphate of Alumina and Potassa)

($KO, SO_3 + Al_2O_3, 3SO_3 + 24HO$.)

261. *Experiment.*—Saturate two ounces of boiling water with sulphate of potassa, and add to it the solution of sulphate of alumina, obtained at § 259. Stir the mixture till it is cold, and decant the clear liquor from the white sediment. The sediment is *alum* in a state of powder. If dissolved in boiling water and

slowly cooled, you obtain from it crystallised alum in beautiful, transparent, four-sided double pyramids (octahedrons).

Fig. 188.



Thus alum is a combination of two different salts—it is a *double salt*. The two salts, sulphate of potassa and sulphate of alumina, have united *chemically* together, for a new body with new properties is formed from them; they have united *chemically* with each other, for definite quantities of both salts have entered into combination—namely, half an ounce of sulphate of potassa and an ounce of sulphate of alumina; or, more accurately, 1 at. $K\,O, S\,O_3$, and 1 at. $Al_2\,O_3, 3\,S\,O_3$. Alum is difficultly soluble in cold water, easily so in hot water, has an acid reaction, and, like all the salts of alumina, has an astringent taste.

262. *Experiments with Alum.*

Experiment a.—Heat a small crystal of alum before the blow-pipe; it foams and melts, forming a white porous mass (burnt alum); the foaming is owing to the evaporation of the water of crystallisation, which constitutes nearly one-half of the weight of the alum.

Experiment b.—Hydrate of alumina is precipitated by carbonate of soda from alum, in the same manner as from sulphate of alumina.

Experiment c.—Boil half an ounce of Brazil-wood for fifteen minutes in six ounces of water, decant the decoction, and dissolve in it half an ounce of alum; it thereby acquires a more brilliant red colour. Now add to it a solution of carbonate of potassa or of soda, as long as any precipitate is produced; this precipitate is of a fine red colour, and, when dried, constitutes the Brazil-wood lake of commerce. In a similar manner, coloured precipitates (*lakes*) are obtained from other vegetable colouring substances. This example serves to show the powerful *attraction* which alumina has for *colouring matter*. Almost all colours of the animal and vegetable kingdom may be precipitated by alumina from their solutions, which accounts for the great importance of the alumina salts in dyeing and calico-printing. For this purpose, the *acetate of alumina* is very frequently substituted for alum, because the feeble acetic acid more readily leaves the alumina than the strong sulphuric acid does. It is obtained by mixing together a solution of acetate of lead and sulphate of alumina (or alum), whereby, by double elective affinity, *soluble acetate of alumina* (alum mordant) and *insoluble* sulphate of lead are formed.

Experiment d.—Moisten a piece of alum (or clay or alumina) with a drop of a solution of nitrate of cobalt, and heat it before the blow-pipe; the nitric acid is driven off, but the oxide of cobalt, which remains behind, imparts a *beautiful blue* colour to the compound of alumina. This fact is frequently taken advantage of, as very accurate means of detecting alumina. By a similar process, a valuable and very beautiful blue pigment is prepared, called *smalts*.

Another splendid blue pigment, *ultramarine*, has been made within a few years, by heating to redness a mixture of alumina, sulphuret of sodium, and a trace of iron. This pigment must be carefully kept from contact with acids, as they would evolve from it sulphuretted hydrogen, and destroy the colour.

263. Alum is not prepared on a large scale directly from clay and sulphuric acid, but from rocks containing alumina and also sulphur (pyrites); for instance, aluminous slates or shales. If these rocks are allowed to remain for some time exposed to the air (*weathering*), or are moderately heated (roasted), there is formed from the sulphur sulphuric acid, which now combines with the alumina.

264. Alum affords a fine example for elucidating the principle of so-called *isomorphism*. For instance, we are able to replace the potassa in the alum by another simple atomic base, namely, soda or ammonia; or to replace the alumina by another sesquibase, namely, sesquioxide of chromium or sesquioxide of iron, without thereby changing the octahedral crystalline form. We thus obtain the following kinds of alum:

Potassa alum,	consisting of	sulphate of	alumina	+	sulphate of	potassa.
Soda alum	"	"	"	+	"	soda.
Ammonia alum	"	"	"	+	"	ammonia.
Chrome alum	"	"	chrome	+	"	potassa (soda or ammonia).
Iron alum	"	"	iron	+	sulphate of	potassa (soda or ammonia).

These combinations are said to be *isomorphous* (from ἴσος, *equal*, and μορφή, *form*), or having the same form, because they possess a similar *constitution* and the same *crystalline form* (octahedron). The term alum is now applied, also, to some of the double salts, in which no alumina is present. The three first of the alums mentioned have a white colour, chrome alum, a deep red, and iron alum, a pale violet colour. They may easily be prepared by dissolving together in water their simple constituent salts, in proper proportions, and putting the solution aside to crystallise.

Occurrence of Alumina in Nature.

265. Next to silica, alumina occurs most frequently in nature, and, indeed, not only in clay and loam, but also in rocks and minerals; for instance, in the well-known grey-coloured clay-slate, porphyry, &c. *Felspar* must be regarded as the most important of the aluminous minerals, and is found in greater or less quantity in granite, gneiss, mica-slate, and other rocks. In its constitution it has the greatest similarity to alum, except that it contains silicic, instead of sulphuric, acid:

Alum (anhydrous) $(K\,O, S\,O_3 + Al_2\,O_3, 3\,S\,O_3)$;
Felspar $(K\,O, Si\,O_3 + Al_2\,O_3, 3\,Si\,O_3)$.

Felspar, like all other stones, is finally disintegrated by the influence of air and water, and by heat and cold; it weathers, as the miners say, or is dissolved, and the silicate of potassa is thereby gradually removed by the water, so that, as the result of this decomposition, clay or loam remains behind $(Al_2\,O_3, 3\,Si\,O_3)$. When the farmer lets his ploughed land lie *fallow*, that is, remain uncultivated for some time, he, by this means, accelerates the weathering; soluble salts of potassa, soda, lime, and other salts, are thereby formed from the constituents of the soil, and to these salts especially is to be attributed the greater fertility of fallow land over that which has been exhausted by cultivation.

266. Glucinum, Yttrium, Zirconium, Thorium, and the recently-discovered Erbium, Terbium, and Norium, are very rare elements, the combinations of which with oxygen are white, insoluble, and earthy, like aluminum, and are called Glucina, Yttria, Zirconia, &c.

RETROSPECT OF THE EARTHS (ALUMINA, &c.).

1. The earths are combinations of the metals of the earths with oxygen.

2. They are entirely *insoluble* in water.

3. They do *not* combine with carbonic acid.

4. The most important of these earths is *alumina*, which, combined with silica (*clay*, *loam*), forms a principal ingredient of soils, and of many kinds of rocks.

5. Alumina is a much weaker base than the alkalies and alkaline earths.

6. Weak bases, as if they were acids, combine with strong bases.

7. Many bodies may, in chemical combinations, replace another body, atom for atom, without a change of the crystalline form taking place (*isomorphous* substances).

8. *Neutral salts* are salts in which, for every atom of oxygen which the base contains, there is an atom of acid.

9. Many neutral salts may combine with one or several atoms of acids; such combinations are called *acid salts*.

10. There are also combinations of neutral salts with one or more atoms of bases; they are termed *basic salts*.

11. When two different salts unite chemically with each other, they are called *double salts*.

RETROSPECT OF THE (LIGHT) METALS HITHERTO CONSIDERED.

1. The metals of the alkalies, of the alkaline earths, and of the earths, are called *light metals*, because they are *specifically lighter* than the other metals.

2. They never occur in nature as pure metals, neither as pure oxides (with the exception of alumina), but always as *salts*, and constitute, together with silica, the principal portion of our earth.

3. Of all bodies, they have the greatest affinity for *oxygen*, and form with it oxides, which (with the exception of the earths) *dissolve* in water.

4. The oxides of the metals of the alkalies, and of the alkaline earths, are the *strongest bases* (alkalies, alkaline earths).

5. On account of their great affinity for oxygen, the preparation of the light metals is very difficult, since the combination between the metal and oxygen can only be destroyed in the strongest heat by charcoal, or by the galvanic current. Only potassium, sodium, and aluminum are as yet accurately known.

6. Until the year 1807 the alkalies and earths were regarded as simple bodies; but at that time the celebrated chemist, Davy,

succeeded in resolving them into metals and oxygen, by means of the galvanic current.

7. *Most* of the light metals are able to decompose water, even at ordinary temperatures, and without the aid of an acid; that is, to withdraw from it the oxygen, and consequently liberate the hydrogen.

LAWS OF CHEMICAL COMBINATION.

Before proceeding to the consideration of the other metals, it will be well to revert to the laws of chemical combination, often mentioned in the foregoing pages, and to reduce them to a methodical system.

267. *Classification of Chemical Combinations.*—As innumerable words may be formed from the twenty-six letters of our alphabet, so likewise innumerable compounds may be prepared from the sixty-two chemical elements. These may be classed in three great divisions. Combination of the *first order* are formed when elements unite with elements; to this belong, for instance, acids and bases. When these are combined together, we obtain combinations of the *second order*, for instance, *salts.* From the union of the salts with salts are produced combinations of the *third order*, for instance, double salts. We find something quite analogous to this in the construction of our language. From letters we form *syllables*, from syllables single *words*, and from single words *compound words.*

268. *When bodies combine chemically with each other, it is always in certain fixed and invariable proportions.* Water, in whatever condition it may exist, whether in springs or in the sea, as ice or vapour, is uniformly composed of 1 ounce of hydrogen and 8 ounces of oxygen. When artificially prepared by burning hydrogen in oxygen gas, exactly the above proportion of each gas is required, that is, 1 grain, ounce, or pound of hydrogen is required for every 8 grains, ounces, or pounds of oxygen. If 1½ ounce of hydrogen be taken, half an ounce of hydrogen remains behind; or if 9 ounces of oxygen are taken, then an ounce of oxygen remains behind. Quicklime, whether prepared from marble or limestone, from chalk or oyster-shells, invariably contains 20 ounces of calcium and 8 ounces of oxygen; and sulphuric acid, whether manufactured by the Nordhausen

method, from green vitriol, or, according to the English method, by the combustion of sulphur, always contains 16 ounces of sulphur to 24 ounces of oxygen.

269. It has also been ascertained, by the most accurate investigations, how many parts by weight of the other elements combine with one part by weight of hydrogen. Since these quantities, as will hereafter appear, are of great importance in chemistry, the numbers representing those of the most common elements are given, as follows:

Eight ounces of oxygen, = O, combine with

1	ounce of	hydrogen,	or	H.	40	ounces of	potassium,	or	K.
14	"	nitrogen,	"	N.	23	"	sodium,	"	Na.
6	"	carbon,	"	C.	18	"	ammonium,	"	NH_4.
16	"	sulphur,	"	S.	20	"	calcium,	"	Ca.
32	"	phosphorus,	"	P.	69	"	barium,	"	Ba.
36	"	chlorine,	"	Cl.	12	"	magnesium,	"	Mg.
80	"	bromine,	"	Br.	14	"	aluminum,	"	Al.
127	"	iodine,	"	I.	28	"	iron,	"	Fe.
26	"	cyanogen,	"	Cy.	28	"	manganese,	"	Mn.
11	"	boron,	"	Bo.	30	"	cobalt,	"	Co.
22	"	silicon,	"	Si.	30	"	nickel,	"	Ni.
32	"	zinc,	"	Zn.	108	"	silver,	"	Ag.
59	"	tin,	"	Sn.	99	"	platinum,	"	Pt.
104	"	lead,	"	Pb.	197	"	gold,	"	Au.
213	"	bismuth,	"	Bi.	27	"	chromium,	"	Cr.
32	"	copper,	"	Cu.	75	"	arsenic,	"	As.
200	"	mercury,	"	Hg.	129	"	antimony,	"	Sb.

These numbers are called *combining proportionals*, because they express the proportion in which an element chemically combines with 8 parts of oxygen. If we now wish to ascertain the composition of potassa, or of oxide of mercury, we have only to refer to the table, and we find, that in potassa 40 ounces or parts of potassium combine with 8 ounces or parts of oxygen, and that in the oxide of mercury, 200 ounces of mercury combine with 8 ounces of oxygen.

Accordingly, the elements with the smaller proportional numbers must be regarded as more powerful than those with larger proportional numbers. Potassium, for instance, is 5 times stronger than mercury, since 40 ounces of it unite with the same quantity of oxygen that 200 ounces of mercury do.

270. *Equivalents.*—Further experiments have led to the surprising discovery, that these numbers not only indicate in what proportion the elements combine with oxygen, but also in what quantities they combine *with each other.* These quantities

are the same as those of the proportional numbers. 1 ounce of hydrogen combines exactly with 8 ounces of oxygen, forming water; with 16 ounces of sulphur, forming sulphuretted hydrogen; with 36 ounces of chlorine, forming muriatic acid. The same quantity of sulphur which, with 24 ounces of oxygen, formed sulphuric acid, yields, with 40 ounces of potassium, sulphuret of potassium, with 28 ounces of iron, sulphuret of iron, and with 100 ounces of mercury, persulphuret of mercury (cinnabar). If the iron is heated with cinnabar, the sulphur passes to the stronger iron, and the mercury is set free. 28 ounces of iron are thus just sufficient to decompose 116* ounces of cinnabar, and consequently to liberate 100 ounces of mercury. If more iron is employed, a portion of it remains uncombined; if more cinnabar, a part of it remains undecomposed. *When in a chemical combination one element replaces another, it always happens in the quantities specified by the combining proportionals.*

For the same sum can be bought 6 ounces of gold, or 12 ounces of platinum, or 100 ounces of silver, or 1500 ounces of mercury; consequently, 6 ounces of gold have the same mercantile value as 12 ounces of platinum, or 100 ounces of silver, &c. The same principle holds good in chemistry. 28 ounces of iron, 40 ounces of potassium, or 200 ounces of mercury, combine with 8 ounces of oxygen; accordingly, 28 ounces of iron have the same chemical value as 40 ounces of potassium, or 200 ounces of mercury. This is the reason why these numbers are likewise termed *equivalents* (from *æquus*, equal, and *valor*, value). Thus, by one equivalent of oxygen is to be understood 8 parts of it by weight; by one equivalent of iron, 28 parts by weight; and by one equivalent of mercury, 200 parts by weight, &c.

271. *The same law of equivalent proportion applies also to the chemical combinations of the second and third order*, to which the process of a neutralisation of a base by an acid, and the capacity of saturation of acids, referred. (§ 200.) When the basic properties of a base, and also the acid properties of an acid, have disappeared, then these two bodies have united with each other in precisely those quantities which are *determined by the natural law.* The amount of this quantity for each body

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* Cinnabar is composed of mercury 200 + sulphur 32 = 232.

may easily be ascertained by adding together the equivalent numbers of their component parts.

Chalk is carbonate of lime ($Ca\,O,\ C\,O_2$).

Lime consists of		*Carbonic Acid* consists of	
1 eq. of calcium	= 20	1 eq. of carbon	= 6
and 1 eq. of oxygen	= 8	and 2 eq. of oxygen	= 16
Combining number of $Ca\,O$	= 28	Combining number of $C\,O_2$	= 22

That is, in chalk 28 ounces of lime are always combined with 22 ounces of carbonic acid, and exactly the same proportion must be used in the artificial preparation of chalk from its constituents. The combining proportion, or equivalent number, of chalk is accordingly = 50.

If we wish to convert chalk by common sulphuric acid into *sulphate of lime* ($Ca\,O,\ S\,O_3$), we must first seek for the proportional number of the acid. We commonly find in it one equivalent of anhydrous sulphuric acid, united with one equivalent of water.

The constituents of sulphuric acid are		The constituents of water are	
1 eq. sulphur	= 16	1 eq. hydrogen	= 1
and 3 eq. oxygen	= 24	1 eq. oxygen	= 8
Eq. of $S\,O_3$ is thus	= 40	Eq. of $H\,O$ is thus	= 9

Consequently, the combining proportion of common sulphuric acid is 49. This quantity just suffices to convert the above obtained 50 ounces of chalk into sulphate of lime. The carbonic acid which thereby escapes amounts to 22 ounces.

Sulphate of lime combines always with two equivalents of water of crystallisation; its constituents are, consequently,—

1 eq. of $Ca\,O$ = 28
1 eq. of $S\,O_3$ = 40
and 2 eq. of $H\,O$ = 18

Equivalent number of cryst. sulphate of lime = 86 = $Ca\,O,\ S\,O_3 + 2\,H\,O$.

If you heat it, the water is expelled, and there remains for calcined or anhydrous sulphate of lime the equivalent 68. It is evident that water enters into chemical combinations with the acids, bases, or salts, not as being essential to their constitution, but only as forming a portion of them.

Previously to the discovery of this law, hardly fifty years ago, it could only be ascertained by laborious trials how much of one body was required to combine with another, or to replace another; it is now only necessary to refer to the table of the proportional or equivalent numbers to ascertain *beforehand* the quantity to be employed.

272. *Multiple Proportions.* — Many elements have the capacity of combining with three, four, five, or even more proportions of oxygen, sulphur, chlorine, &c., thus producing the different oxides, sulphurets, chlorides, &c., described in section 154. This would at first seem to be inconsistent with the law that bodies always combine with each other in fixed proportions; but on more mature consideration of the subject, it will be obvious that no inconsistency exists, and that these greater or less quantities are *not* promiscuously compounded, but that they are likewise combined in *fixed* and *invariable* proportions.

If we ascend a hill, it is at our own option to take many or few, long or short steps, since the inclination is not interrupted by perpendicular acclivities; but on mounting a flight of stairs or a ladder, a determinate and regular number of steps only can be taken. In like manner, bodies which combine in several proportions with another body do so in different, but yet in invariable quantities, and such combinations always take place in ratios of $1\frac{1}{2}$, 2, $2\frac{1}{2}$, 3, or $3\frac{1}{2}$, but never in ratios of $1\frac{1}{4}$, or $1\frac{3}{4}$, or $1\frac{7}{8}$, &c. The ascent takes place, as it were, only by whole or half steps; thus, for instance,—

6 oz. of carbon form, with	8 oz. of oxygen,	carbonic oxide	$= C\,O.$
	12 " "	oxalic acid	$= C_2\,O_3.$
	16 " "	carbonic acid	$= C\,O_2.$
14 oz. of nitrogen form, with	8 oz. of oxygen,	nitrous oxide	$= N\,O.$
	16 " "	nitric oxide	$= N\,O_2.$
	24 " "	nitrous acid	$= N\,O_3.$
	40 " "	nitric acid	$= N\,O_5.$
28 oz. manganese form, with	8 oz. of oxygen,	protoxide of manganese	$= Mn\,O.$
	12 " "	sesquioxide of manganese	$= Mn_2\,O_3.$
	16 " "	peroxide of manganese	$= Mn\,O_2.$
	24 " "	manganic acid	$= Mn\,O_3.$
	28 " "	permanganic acid	$= Mn_2\,O_7.$

In the combinations of carbon, the ratio of the oxygen is as . . . $1 : 1\frac{1}{2} : 2$

In the combinations of nitrogen, the ratio of the oxygen is as . . . $1 : 2 : 3 : 5$

And in the combinations of manganese, the ratio of the oxygen is as . . $1 : 1\frac{1}{2} : 2 : 3 : 3\frac{1}{2}$

It is obvious that these numbers stand in a very simple ratio to each other, and that the larger numbers are multiples of the smaller number; this is expressed by calling it the *law of multiple proportions.*

273. *Gaseous bodies always combine with each other in certain volumes.* The volume of the gases is very often less, after combination, than the sum of their volumes in the separate state.

Examples.

From 1 vol. of chlorine and 1 vol. of hydrogen are formed 2 vols. of hydrochloric acid gas.

From 2 vols. of hydrogen and 1 vol. of oxygen are formed 2 vols. of aqueous vapour.

From 3 vols. of hydrogen and 1 vol. of nitrogen are formed 2 vols. of ammoniacal gas.

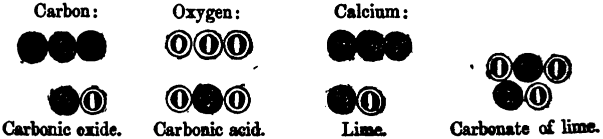
From 6 vols. of hydrogen and 1 vol. of sulphur are formed 6 vols. of sulphuretted hydrogen gas.

Thus the same constancy characterises the combinations by volumes as those by weight, and they are marked by a still greater simplicity. And if it were possible to convert all bodies into gases, probably a similar simple proportion by measure or volume would be observed in all chemical combinations.

274. *Atoms.*—After having proved by a vast number of facts, the result of the most laborious investigations, that chemical combinations always take place according to fixed volumes and weights, the cause of this wonderful immutability is sought for. A thinking man, when he knows *that* a thing happens, and *how* it happens, will always inquire, *Why* is it thus, and not otherwise? This question could not be solved by any effort of experiment and observation; but reflection has enabled us to arrive at an idea by which we can explain to ourselves this regularity and unchangeableness. This idea has received the name of the *atomic theory.* It is as follows:

1.) Every substance is composed of small particles, which lie in contact with each other, and are called *atoms;* between these atoms there are interstices or pores. In light bodies the atoms are more remote from each other, and the interstices are larger, than in heavy bodies. When substances are subjected to cold or pressure, the atoms approximate more closely, and the bodies become denser and specifically heavier, while, if heated, the atoms separate from each other, the pores become larger, and the bodies consequently more expanded and specifically lighter. The atoms are farthest distant from each other in gases and vapours; in steam, for instance, they are 1700 times more remote than in liquid water, since the former occupies 1700 times more space than the latter.

2.) Simple bodies have *simple atoms*, compound bodies, *compound atoms*. For example,—

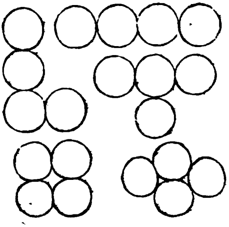


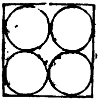
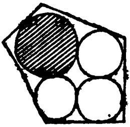
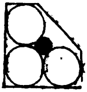
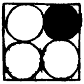
3.) These small particles, of which the mass of a body consists, cannot be further divided into smaller particles. Thus is explained the name *atomos* (that which cannot be divided).

4.) They are so *small* that they can neither be seen nor counted, even by means of the most powerful magnifying-glass; and they have, therefore, only an imaginary existence.

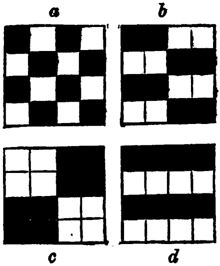
5.) When a solid body separates slowly from a fluid, its atoms have time to arrange themselves beside each other in a definite manner, and we obtain *regular crystals;* but on becoming suddenly solid, an *irregular* disposition of the atoms takes place, and the body appears *amorphous* (vitreous or pulverulent).

6.) The position of the atoms towards each other *may be varied.* As four balls may be put in the following positions, so atoms also may lie beside each other, arranged sometimes in one and sometimes in another manner. Thus is explained why one and the same substance may often appear in different forms of crystallisation, or with a different structure, consequently in two different states (dimorphous). Sulphur, at ordinary temperatures, crystallises from its solutions in octahedrons; but when fused, it crystallises on cooling in oblique prisms. (§§ 125, 126.) A newly-forged iron axle has a fibrous texture, but after being used for some time its texture becomes granular.



7.) The atoms of different bodies have also probably a different *size*. A regular square may be constructed of four peas;  but if we replace one of the peas by a bean  or by a mustard-seed,  then in both cases the regular form is disturbed; it remains, however, unchanged, when a ball of lead of the same size as the pea  is substituted for it, though the square will now present a different appearance. This is an illustration of what occurs with the atoms. We have seen, in the case of the alums, that the potassa may be replaced by soda or ammonia, or the alumina by sesquioxide of chromium or sesquioxide of iron, without changing the form of the crystals. We therefore conclude that potassa, soda, and ammonia have equally large atoms; they are isomorphous (of the same shape); the same applies also to alumina, and to sesquioxide of chromium and of iron. If we see, on the contrary, that a change takes place in the form of the crystals when we replace one body by another, we thence infer that there is an unequal size of the atoms in these bodies.

8.) The *isomeric* state of bodies is explained very simply by the atomic theory. The most manifold and regular groupings may be produced on a chess-board by transposition of the white and black squares; for instance,—



Each figure is composed of eight white and eight black squares, but though the absolute number is the same, the grouping is different. In *a*, one and one, in *b*, two and two, in *c* and *d*, four and four, squares are so joined together as to present a different appearance. If we imagine these squares to be atoms, we obtain an idea of isomeric bodies, and it is thus rendered clear how there may be bodies of the same constitution and form, yet presenting an entirely different appearance, and possessing different properties. Those exceedingly dissimilar bodies, caoutchouc (gum elastic), petroleum, and illuminating gas, afford a striking example of external difference and internal conformity. They have the same constituents (carbon and hydrogen) both in quality and relative quantity.

9.) The atoms of the different bodies must finally possess also *weight*, and, indeed, very different degrees of it. If a piece of chalk, containing perhaps a million of atoms, has a fixed weight, so also must the smallest particle of it possess weight, however slight it may be; for a body having weight can never be formed of a body having no weight. Chalk always contains 28 ounces of lime, and 22 ounces of carbonic acid. If a large piece of chalk has this constitution, so a smaller piece, even the minutest particle, must contain the same proportions. If we suppose chalk to be composed of one atom of lime, and one atom of carbonic acid, we ascribe to the atom of lime a weight of 28, and to the atom of carbonic acid a weight of 22. In 28 ounces of lime are always contained 20 ounces of calcium and 8 ounces of oxygen; this combination, also, is to be regarded as consisting of equal atoms; accordingly, one atom of calcium weighs 20, and one atom of oxygen 8. Finally, in 22 ounces of carbonic acid are always contained 6 ounces of carbon united with 16 ounces of oxygen; wherefore 6 is to be regarded as the weight of an atom of carbon, and 16 as that of two atoms of oxygen.

The numbers are exactly the same as those given in the list of proportional or equivalent numbers. Thus these numbers in an atomic point of view may be regarded as the *relative weight of the atoms;* hence the third and simplest name for them, *atomic weights.*

HEAVY METALS.

FIRST GROUP OF THE HEAVY METALS.

IRON, FERRUM (Fe).

At. Wt. = 28. — Sp. Gr. = 7.

275. If gold is called the king of metals, *iron* must be deemed by far the most important and useful subject in the metallic realm. Iron was formerly regarded as the symbol of war, and received the name of Mars, and the symbol ♂; but who does not know that it has now attained also a great, an indescribably great importance in the peaceable occupations of men? It is not only converted into swords and cannons, but into ploughshares and chisels, and into a thousand other implements and machines, from the simple coffee-mill to the wonderful steam-engine. It is the ladder upon which the arts and trades have mounted to such an extraordinary height. It is the bridge upon which we now glide over mountains and valleys with the rapidity almost of magic.

Pure gold is found on the surface of the earth, and it is only necessary to free it from earthy admixtures to obtain it in a pure metallic state. Not so with iron. The ore in which this lies imbedded must be procured from the earth by skilful operations, and its oxygen expelled by ingenious methods, and by exposure to the hottest fire, in order to convert it into metallic iron; the latter must again be fused and refined by different operations before it can be forged and welded. Gold is presented to men by nature as a gift, but iron must be struggled for by the most laborious toil, by exertion both of the bodily and mental powers. Thus iron has become a blessing to those countries whose inhabitants are occupied with the mining and working of it; for, as history teaches, in those countries are found the blessings attendant on labour, health, contentment, prosperity, and intellectual culture, in a far greater degree than in those countries where gold abounds and industry is neglected.

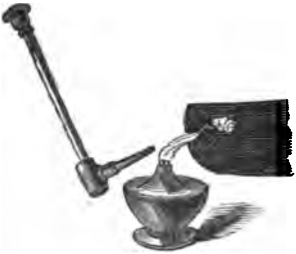
In another respect, also, iron, of all the heavy metals, appears to be the most important to mankind. It is the only metal which is not injurious to the health, the only metal which forms a never-failing constituent of the body, especially of the blood; the only metal, finally, which is found everywhere on the earth, in all stones and soils, and in almost every plant. Although we are ignorant wherein consists the influence which it exercises upon the life of animals and plants, yet its universal diffusion must lead us to conclude that it has pleased the Highest Wisdom to invest iron with an importance for organic life similar to that possessed by common salt, lime, phosphoric acid, and some other substances.

Experiments with Iron (Iron Ores).

276. For these experiments *fine iron filings* are employed, such as are kept in chemists' shops.

Experiment a.—Place 14 grains of iron filings upon a piece of charcoal, and heat it for some minutes in the flame of the blow-pipe, directed upon one spot; it becomes red-hot, and the heat spreads throughout the whole mass, as is apparent from the iridescent tints, which precede the red heat. The iron on cooling acquires a darker, almost a black colour, and bakes into a coherent mass weighing about 15 grains. Thus, 14 grains have combined with 1 grain of oxygen. If you multiply these numbers by 2, you obtain 28 grains of iron (1 atom), and 2 grains of oxygen ($\frac{1}{4}$ atom), or four atoms of iron to one atom of oxygen. This body may be termed *suboxide of iron.* In the protoxide of iron, one atom of iron (28) always combines with one atom of oxygen (8); consequently the suboxide may be regarded as a mixture of one atom of protoxide of iron and three atoms of metallic iron.

Fig. 139.



Experiment b.—Subject again the above mass to a red heat, for a longer period, in the blow-pipe flame. It continues to increase in weight until it has finally gained from four to five grains more. It now forms the same combination as was produced by the burning of iron in oxygen, and in the forging and welding of iron, namely, the well-known *iron cinders.* It is a mixture of *protoxide* and *sesquioxide* of iron. The protoxide (Fe O) cannot be prepared in a pure state by this method, as sesquioxide is always simultaneously formed; but from the colour of the suboxide and of the black oxide, it may be inferred that it has a black colour. We perceive this colour, also, in all those rocks which contain protoxide of iron, generally in combination with silicic acid. Almost all black and green stones, for instance, basalt, clay-slate, greenstone, serpentine, &c., owe their colour to protoxide of iron.

An iron ore, which has the same constitution and the same black colour as iron scales, occurs abundantly in many places. It is called *magnetic oxide of iron*, and is not only attractable by the magnet, but is itself likewise magnetic. A small magnet may be prepared by placing a piece of magnetic iron ore (loadstone) between two rods of iron, when the magnetic force passes from the stone into the iron. The celebrated Swedish iron is mostly obtained from this variety of iron ore.

Experiment c.—Iron cinders, when exposed for a long time to the outer or oxidising blow-pipe flame, become covered with a red pulverulent coating; they take yet more oxygen from the air, and become *sesquioxide of iron* ($Fe_2\ O_3$).

Experiment d.—The sesquioxide of iron may be prepared more easily in the following manner. Place a crystal of green vitriol upon charcoal, and heat it until it has become of a brownish-red colour. The water and sulphuric acid escape, and the protoxide of iron ($Fe\ O$) remaining behind absorbs one half as much again oxygen, and becomes converted into sesquioxide of iron ($Fe_2\ O_3$). The red colour of the latter is more clearly brought out by rubbing it on paper with the nail. In the same manner, sesquioxide of iron remains behind when green vitriol is heated in the preparation of oil of vitriol; this forms an article of commerce under the name of *caput mortuum*, English or polishing rouge, and is a favourite and cheap pigment for varnish, and is also used in the polishing of glass and metals.

Sesquioxide of iron occurs native in many places of the earth, sometimes crystallised, as in *iron-glance;* sometimes compact, as in *brown hematite;* or radiated, as in *red hematite;* or earthy, as in *red ochre.* It is often also mixed with clay, and is then called *clay iron-stone.* The colouring matter of red stones or earths is owing to the presence of sesquioxide of iron. Many of the above-named bodies form immense beds in the interior of the earth, and are used as valuable ores (*red iron-stone*) for the manufacture of iron.

Experiment e.—Introduce some iron filings into a tumbler, and fill it with spring-water; the iron will gradually lose its lustre, and assume a black colour; it is converted into magnetic oxide of iron. Repeat this experiment with water that has been boiled; in this, the iron will retain its metallic lustre. The cause of this difference is owing to the air and carbonic acid, which are present in all spring-water, and slowly oxidise the iron. These gases are expelled by boiling, therefore no oxidation takes place in water that has been boiled.

Experiment f.—If you now pour off the water, so that the iron comes in contact also with the air, *rust* begins to form upon it. The iron absorbs so much oxygen that it becomes a sesquioxide; it also absorbs a definite quantity of *water* (3 atoms), which may be regarded as the cause of the yellow colour of rust. Rust is therefore *hydrated sesquioxide of iron* ($Fe_2\ O_3$, $3\ H\ O$). If you keep the iron moist, and stir it round several times every day, it will, after a time, be completely converted into rust.

This combination frequently occurs also in nature, and is used as an excellent iron ore, under the name of *brown iron ore.* When mixed with clay it is called *yellow clay ironstone, yellow ochre,* &c. The yellow or brown colour which we see in so many stones when they are exposed to the air, the yellow or brown colour of the soil, loam, or sand, always proceeds from the hydrated sesquioxide of iron. The weathering of black varieties of stone to a brown stratum, and finally to a yellow soil, will now no longer appear strange; the black protoxide of iron contained in them is gradually oxidised into a yellow hydrated sesquioxide of iron.

Experiment g.—Put a small quantity of the magnetic oxide of iron obtained by *b*, or some iron filings, into a phial; fill the latter with artificial Seltzer-water, and let it stand, well stopped up, for one day. The white flakes which deposit on the bottom of the phial are *carbonate of the protoxide of iron*, formed from the protoxide of iron of the iron cinders, and from the carbonic acid of the Seltzer-water. The chemically combined water in this case communicates a white colour to the black protoxide of iron. The clear liquid also contains some of the carbonate of iron in solution, as is evident from the *inky taste* peculiar to solutions of iron. It is then to be poured into a tumbler, and left for some time exposed to the air. In proportion as the free carbonic acid escapes, the surface is covered with a delicate white pellicle, the colour of which gradually changes to yellow, then to red and violet; finally, the pellicle assumes a yellowish-brown colour, and falls as rust to the bottom. *Protoxide of iron attracts oxygen with great avidity, and is converted into magnetic oxide of iron, and finally into hydrated sesquioxide of iron.* The salts of protoxide of iron act also in the same manner; this is the reason of their becoming yellow by long keeping, or by exposure to the air. A very thin pellicle of magnetic oxide of iron gives a yellow reflection; a thicker pellicle, a red or brown, and a still thicker one, a violet and blue reflection; this explains the iridescent changes of colour presenting such a beautiful appearance on the surface of standing waters. In those places where spring-waters flow over stones containing iron, natural solutions of carbonate of iron (*chalybeate waters*) frequently occur, which are likewise decomposed by the air. This decomposition of the carbonate of iron is the source of the brown mud which is deposited in large quantities from some waters. By the accumulation of this mud, large beds of hydrated sesquioxide of iron are formed, known under the name of *bog-iron ore*, and from which iron is worked. This ore usually contains also some phosphoric acid.

The *carbonate of protoxide of iron* is found in many countries in the form of a light grey massive stone, and in such large quantities that iron is obtained from it. The famous Styrian steel is principally prepared from this ore, which is called *spathic iron ore*, or spherosiderite. Mixed with clay, it very frequently occurs associated with common coal, and it is from this ore that most of the English iron is obtained.

277. In attending to the combinations which iron yields with oxygen, we have also become acquainted with the most important iron ores from which iron is prepared on a large scale. They are the following:

$Fe\,O + Fe_2\,O_3$, or magnetic iron ore.

$Fe\,O, C\,O_2$, or spathic iron (clay iron-stone, spherosiderite).

$Fe_2\,O_3$, or specular iron (red hematite, iron-glance, &c.).

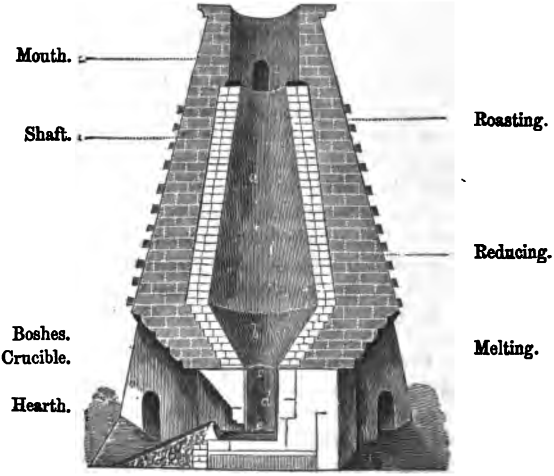
$Fe_2\,O_3 + 3\,H\,O$, or brown iron ore (yellow iron-stone, yellow ochre, &c.).

Cast-Iron, Bar-Iron, and Steel.

278. *Working of Iron.*—In order to extract metallic iron from the ores just mentioned, they must be deprived of their oxygen. This is generally done by exposing them with charcoal to a red heat. As a general rule, a mixture of several

kinds of ore is used for smelting, because experience has taught that this process is then conducted more easily and more completely than when only one kind of iron ore is employed. The ores, containing carbonic acid, water, or sulphur, must previously be heated in appropriate furnaces to expel these volatile gases (*roasting of the ores*). It must also be borne in mind that the iron ores are never pure, but always contain foreign ingredients (*gangues*); for instance, silica, clay, lime, manganese, phosphorus, &c. *Silica* especially forms a principal ingredient in iron ores. This does not melt even when exposed to the hottest furnace-fire; and yet it must be melted, that the iron may flow from the ores, and be obtained as a coherent mass. This is effected by the addition of a base, commonly lime, with which the silicic acid will combine. A lime-glass is formed, and if loam or clay be present also an alumina-glass, both of which, when combined, melt more readily than each separately, and flow off as *slag*. The substance which forms this fusible compound is termed the *flux*; and the combination of the prepared ore and the flux is called the *mixture*. Alternate layers of this mixture, and of wood-charcoal or of coke are now thrown into a large furnace, called the *blast-furnace*, constructed as shown in the annexed figure.

Fig. 140.



The portion *a* of the blast-furnace is called the *shaft; b* is the *boshes*, *c* is the *crucible* part, and *e* is the *hearth*. The mouth of the furnace serves both for charging the materials, and for the escape of the smoke; it is thus both a door and a chimney. In the upper portion of the shaft the mixture is heated to redness (it is roasted); during this process the carbonic acid of the limestone also escapes. Further down, the charcoal abstracts from the iron ore its oxygen, and escapes with it as carbonic oxide, which at the opening is entirely consumed, on access of air, into carbonic acid, and occasions the bright flame which issues from the top.

In the boshes, where the greatest heat is evolved, the reduced iron melts, and falls in drops upon the hearth, together with the silica, lime, and clay; these form a slag, which floats on the molten iron, and is drawn off at *i*. The melted iron is suffered to flow off from time to time by a small opening made in the side-wall of the hearth. After having heated to two hundred degrees or more the air necessary for burning the charcoal or coke, it is forced at *d*, by means of a large bellows or other *wind apparatus*, into the furnace, in which a heat of perhaps 2192° F. (1200° C.) or 2552° F. (1400° C.) may be produced. In proportion as the melted iron and the slag are removed from beneath, fresh charges of ore, lime, and charcoal are introduced at the top; and in this manner the smelting often continues uninterruptedly for five or six years, according as the furnace holds out.

Iron Ore Flux Fuel	Iron + — Carbon	Oxygen + — Carbon	Silica (clay) Lime (clay) — —
Product	Carburetted Iron (cast-iron).	Carbonic oxide and Carbonic acid.	Silicate of lime and Silicate of alumina } Slag.

The slag from the blast furnaces has generally a green or blue colour, owing to the protoxides of iron and of manganese dissolved in it. It is frequently formed into square blocks, and used for building-stones.

279. *Cast or Crude Iron.*—The metal obtained by the above process is by no means pure iron, but a chemical mixture of iron and carbon. A hundred-weight of iron takes up, at the hottest white heat, from about four to five pounds of carbon, and likewise some silicon from the silicic acid, some aluminum from the

clay, and sometimes also a trace of sulphur, phosphorus, arsenic, &c., when these were contained in the iron ore. Cast-iron, thus obtained, is characterised by the following properties:

a.) It is *fusible* at a white heat (wrought-iron and pure iron are not); therefore it is especially adapted for those iron articles which are made by casting. For remelting iron on a small scale, graphite crucibles are made use of; but on a large scale shaft-furnaces (*Schachtöfen*), or the so-called cupola-furnaces.

b.) Cast-iron is *brittle, and can neither be forged nor welded* (bar-iron and steel may be bent, forged, and welded). The application of cast-iron must, therefore, be limited to the manufacture of such articles as are not exposed to being bent, or to strong concussions. Very recently, however, a method has been discovered for imparting to cast-iron a certain degree of flexibility, and even of malleability, by exposing it for several days with iron scales or spathose iron ore to a red heat. The term *malleable cast-iron* (fonte malléable) has been given to this kind of iron.

There are *two kinds of cast-iron* in commerce, known as grey and white iron. The *grey iron* is almost black, has a granular texture, and admits of being filed, bored, &c.; the *white iron*, on the contrary, is of a silvery whiteness, possesses a lamellar-crystalline texture, and is so hard as not to be acted upon by steel instruments. Crude white iron, by remelting and very slow cooling, is changed to grey; on the other hand, the grey is changed to white iron by being heated and suddenly cooled. Grey iron is best adapted for castings; white iron is the most suitable for the manufacture of bar iron and steel.

280. *Malleable, Wrought, or Bar Iron.*—Cast-iron, by being deprived of its carbon, is converted into *malleable iron*, and acquires the following very important properties:

a.) Bar-iron possesses great *ductility* and *tenacity*, and may be hammered or rolled into sheets, and drawn out into fine wire, which is not the case with cast-iron.

b.) At a less degree of heat than that of fusion it becomes *soft*, like wax or glass, so that two glowing pieces may be welded into one. Upon this property depends its capacity of *being welded*, which is possessed by no other known metal, except platinum. All the other metals become fluid instantaneously, as is the case with ice, without undergoing previous softening.

c.) Wrought-iron is sufficiently soft to be worked by steel instruments, and it does *not* become *harder* if, when heated to redness, it is suddenly quenched in water (steel is thereby rendered brittle).

d.) Wrought-iron is distinguished, moreover, from cast-iron by its *fibrous texture*, composed, as it were, of threads incorporated together; while cast-iron has the appearance of being a baked *granular* mass. But it is a very striking fact that fibrous wrought-iron, by repeated jolts or blows, becomes gradually granular and brittle, as, for example, in the axletrees of carriages. Thus, also, in solid bodies, *their particles or atoms can change their position with regard to each other*, which was formerly supposed to be possible only with liquid bodies. By thoroughly heating and reworking, the former strength and flexibility, as well as the fibrous texture, is restored to the iron.

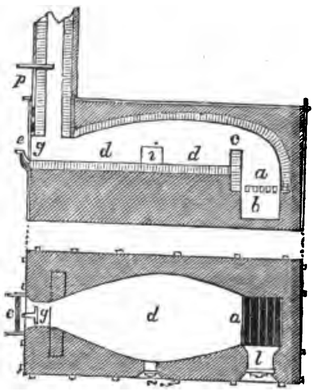
Wrought-iron is not entirely freed from carbon; it contains, however, only from a quarter to a half pound of it for each hundred-weight. Iron entirely free from carbon is softer and more tenacious than bar-iron. Thus we see that it is the chemical combination of the carbon with the iron, as in cast-iron, which destroys these two properties of softness and tenacity.

281. *Refinery of Iron.*—1. *Finery Process.*—The method which is employed for separating carbon from the cast-iron is very simple. The carbon is *burnt out* by heating the iron to fusion, and constantly stirring it while exposed to a current of air, the oxygen of which combines with the carbon, forming carbonic oxide gas. During the operation, a considerable portion of the iron (one quarter) is converted by oxidation into iron cinders, which fuse with the sand, that either adheres to the cast-iron, or is purposely strewed upon the hearth, and form with it a heavy black slag of silicate of magnetic oxide of iron. The iron mass becomes gradually more tenacious, since the iron melts so much the more difficultly the less carbon it contains; and finally, in the form of a loosely coherent mass (the *bloom*) is placed under a loaded hammer, by a few blows of which the remaining slag is pressed out, and the iron particles are formed into a compact mass. The latter is afterwards usually hammered or rolled into bars or bands. This method of converting brittle cast-iron into ductile and malleable iron is called the

finery process. The object of the refinery is, as has just been shown, to *separate the carbon from the iron.* The annexed scheme serves to render the process more intelligible:

Cast Iron	Iron ¾	Iron ¼	Carbon
Air	—	Oxygen	Oxygen
Sand	—	Silica	
Products	Wrought Iron	Slag	Carbonic oxide.

Fig. 141.



2. *Puddling Process.*—For the refining or decarbonising of larger quantities of iron, the reverberatory furnaces are used, similar to those employed in the preparation of soda. (§ 220.) As in these furnaces the fuel does not come in contact with the iron itself, a cheaper fuel than charcoal may be made use of; for instance, coal or turf, the ashes of which, if mixed with the iron, would certainly spoil it. These are called *puddling-furnaces*, because the iron must be kept constantly stirred (*puddled*).

282. *Steel.*—*Steel* holds a middle place between cast and wrought iron, both as to the quantity of carbon it contains, and other properties.

a.) If quenched when heated to redness, it is rendered hard and *brittle* (like cast-iron); if cooled somewhat more slowly, it is rendered *elastic*, and if cooled very slowly, it is soft, *ductile*, and *malleable* (like bar-iron).

b.) It is less fusible than cast-iron, and more so than bar-iron.

c.) It contains, in every hundred-weight, from two to two and a half pounds of carbon.

To these properties steel owes its importance as a material for thousands of articles, especially for cutting instruments, since it may be made soft or hard, elastic or brittle, at pleasure. The article manufactured is usually first heated to redness, then suddenly cooled by quenching it in water, and afterwards *tempered*, in order to diminish its hardness and brittleness.

Experiment.—Hold a steel knitting-needle in the flame of a spirit-lamp till it is red-hot, and then quickly plunge it in cold water; it thereby becomes so brittle as to break on any attempt to bend it. Again hold the needle in the fire, and observe the changes of colour which it passes through; it will first become yellow, then orange, crimson, violet, blue, and finally dark-grey. The cause of this change of colour is the same as that of the ferruginous water (§ 276), namely, a film of oxide forms upon the steel; at first the film is *thin*, and has a *yellow* appearance, but gradually it becomes thicker and also darker, as the heat increases. The final result—the dark-grey coating—is iron scales. On the standing of the ferruginous water in the air, the oxidation advanced (§ 276) a step further; in that case, the final result was a brown substance,—hydrated sesquioxide of iron. A definite degree of hardness and elasticity of the steel corresponds to each of these tints, the needle when covered with the yellow film being the hardest and most brittle, and when presenting a blue aspect being in its softest and most elastic condition. The workmen in steel impart to their articles various degrees of hardness and elasticity by tempering; files and razors are made very hard and brittle,—saws, watch-springs, &c., soft and elastic.

283. Steel may be *prepared* in various ways:—

1.) By partly refining cast-iron, so that only one half of the carbon is burnt out (*crude steel*); or

2.) By the process of cementation, which consists in filling an iron box with bar iron and powdered charcoal, and then maintaining the whole for several days at a red heat. The carbon gradually penetrates into the iron, thus converting it into steel (*blistered steel*).

Both these kinds of steel must be rendered uniform, either by repeated hammering (*tilting*) of it when heated to redness (*tilted steel*), or by remelting (*cast steel*). Steel may be ornamented by corroding its polished surface with acids, whereby a variety of light and dark coloured shades and impressions will be produced.

From the constituents of bar and cast iron it may be inferred that steel can be made by an intimate combination in equal proportions of those two substances. In this manner, indeed, the outer surface of wrought-iron articles—as, for instance, of agricultural implements, chains, &c.—can easily be converted into steel, by being heated in melted cast-iron. This object may be attained more easily by strewing ferrocyanide of potassium over the red-hot iron. (§ 292.)

Iron, nickel, and cobalt, are the only metals which are attracted by the *magnet.* Magnetism immediately vanishes from bar-iron when it is removed from the magnet; while steel, on the contrary, retains its magnetic power, and does not lose it until heated to redness (*steel magnet*). The magnetic oxide of iron is likewise attracted by the magnet, owing to the protoxide contained in it, but the sesquioxide of iron is not so attracted.

Salts of Iron.

284. The protoxide and sesquioxide of iron form salts with acids; we have, accordingly, two series of iron salts:—*a*) the *salts of the protoxide of iron* are generally green, and consist of one atom of protoxide of iron, and one atom of acid; *b*) the salts of *the sesquioxide of iron* are usually of a yellowish-brown colour, and consist of one atom of oxide and an atom and a half of acid (or 2 : 3).

Iron and Acids.

It has already been mentioned (§ 173) that many metals dissolve only in diluted acids, others only in concentrated acids, and that the former take the oxygen requisite for their oxidation from the water, while the latter take it from the acids. Iron, together with manganese, zinc, cobalt, nickel, and tin, belongs to the first-named class of metals, which are called *water-decomposing* or *electro-positive* metals. The mere circumstance, that in the presence of an acid they are able to abstract oxygen from the water, leads to the supposition that they are *more powerful chemical bodies* than those metals which cannot do this. This supposition is in reality confirmed; the electro-positive metals evince a far greater affinity for oxygen, sulphur, chlorine, &c., and their oxides a much greater affinity for the acids, than is exhibited by the other metals and their oxides. It may be well in this place to remind the student that a solution of a metal never contains a metal as such, but always a metallic salt in solution. (§ 160.)

285. *Green Vitriol, or Sulphate of Protoxide of Iron* ($FeO, SO_3 + 7HO$).

This salt, which is always formed when iron is dissolved in diluted sulphuric acid, is often called green vitriol, on account of its pale-green colour. By slowly evaporating the solution, the salt may easily be obtained in oblique rhomboidal prisms; these crystals contain nearly one half their weight of water of crystallisation.

Experiment.—Dissolve 100 grains of blue vitriol (§ 175) in an ounce of water, and introduce into the solution a piece of polished iron, which has been previously weighed; the blue colour will gradually change to green, while the iron is covered with a red coating of copper. The stronger iron takes from the copper its oxygen and sulphuric acid, and combines with both of them; 32 grains of metallic copper are deposited, while full 28 grains of iron have been dissolved; hence as 32 is the atomic weight of copper, and 28 the atomic weight of iron, one atom of copper is replaced by one atom of iron. This process is called *the reduction of a metal by the moist way*. The supernatant liquor no longer contains any copper in solution, but only green vitriol, which may be crystallised by evaporation. Thus is explained the inappropriate name of *copperas*, very commonly applied to sulphate of iron.

Experiments with Green Vitriol.

Experiment a.—Let a solution of green vitriol stand for some time in the air; it will gradually assume a yellowish colour, and a brownish-yellow substance, hydrated sesquioxide of iron, is deposited. All the other salts of protoxide of iron do the same; namely, *they attract oxygen from the air*, and are gradually converted into salts of sesquioxide of iron. But the acid present is not sufficient to dissolve all the oxide, as this has a greater capacity for saturation, that is, requires more acid for its solution than the protoxide of iron does; therefore, a portion of the oxide formed falls to the bottom. *For the same reason, the sesquioxide or peroxide always separates from the protoxide salts of the other metals, when they are converted into higher oxide salts.* A clear solution may be obtained, by adding a sufficient quantity of acid to dissolve the precipitated oxide.

Experiment b.—Boil half an ounce of green vitriol with an ounce and a half of water and one drachm of sulphuric acid, in a porcelain basin, and add a few drops of nitric acid to the solution, until the colour of it is changed to yellow; it now contains *sulphate of sesquioxide of iron* in solution, which must be kept for use. The same effect, namely, the conversion of the protoxide into sesquioxide of iron, is thus *quickly* produced by the oxygen of the nitric acid, which in the former experiment was only *slowly* caused by the action of the air. Three atoms of oxygen are withdrawn from the nitric acid, and, accordingly, nitric oxide is produced (§ 162), which has the property of imparting to a solution of green vitriol a dark colour. On boiling, the nitric oxide escapes, and is converted in the air into nitrous acid, forming the yellow fumes that are given off during the oxidation.

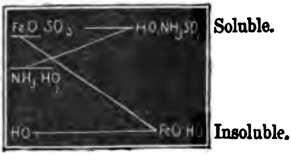
Experiment c.—Prepare (1.) a diluted solution of green vitriol, (2.) a mixture of one part of a solution of sulphate of sesquioxide of iron and four parts of water (see former experiment), and (3.) a mixture of the first and second; and then add ammonia to each of the three liquids, until they emit a distinct ammoniacal odour. There is formed in the

1. Solution of protoxide of iron, a greenish white precipitate of hydrated protoxide of iron;

2. Solution of magnetic oxide of iron, a black precipitate of hydrated magnetic oxide of iron;

3. Solution of sesquioxide of iron, a yellowish-brown precipitate of hydrated sesquioxide of iron.

Ammonia is a stronger base than either protoxide or sesquioxide of iron; for this reason, it abstracts from them their sulphuric acid, and the oxides will be precipitated, since almost all the metallic oxides are insoluble in water. If the metallic oxides, at the moment of their separation from a combination, meet with water, they readily combine with it, forming *hydrates*. This is the reason why the metallic oxides, which are obtained in the moist way, frequently have a very different colour from those prepared in the dry way (by heating to redness). If you heat the hydrate, the water is expelled, and the oxides appear now in their characteristic colour. This change of colour is well illustrated in the case of common bricks, which, before



being burnt, have a yellow colour, owing to the presence of hydrated sesquioxide of iron; when burnt, they are red, because the hydrated water is expelled by the heat, and thereby anhydrous sesquioxide of iron is formed, which possesses a red colour. If the above precipitates are filtered, a striking change is soon perceptible in the protoxide of iron, its colour changing first to a dark green, then to black (magnetic oxide of iron), and finally to brown (hydrated sesquioxide of iron), according to the amount of oxygen absorbed. As already stated, one of the most important properties of protoxide of iron is, that it combines *eagerly with still more oxygen*, a property which, as we have seen, it communicates also to the salts in which it is contained.

The black precipitate of magnetic oxide of iron comports itself in the same manner. But if you boil it previously to filtration, it will retain its black colour on drying.

Experiment d.—If you pour alcohol upon some bruised nutgalls, the liquor, after a few days, will have a brownish-yellow colour, and a very astringent taste. This liquid—called tincture of galls—contains in solution, besides several other ingredients, two organic acids, *tannic acid*, or tannin, and *gallic acid*. Add some of this tincture to a solution of green vitriol, and some of it likewise to a mixture of water and sulphate of sesquioxide of iron; in the former, a *light-coloured* precipitate will be formed, which assumes at first a *violet*, and finally a *black* colour; but in the second liquid a *black colour* is *immediately* produced; and, on standing, a black precipitate will be deposited. This black precipitate consists principally of *tannate* and *gallate of the sesquioxide of iron*. By adding to this gum or sugar, common *ink* is prepared, the mucilaginous or saccharine liquid thus obtained holding the gallate and tannate of iron in suspension. The combination of tannin and gallic acid with protoxide of iron is not black, but it becomes so on exposure to the air, since the protoxide is thus converted into sesquioxide. This explains the pale colour of fresh ink, and its becoming dark on the paper. If you dip a linen rag first in tincture of galls, and then in a solution of iron, the black precipitate is formed in the fibre itself, and thus adheres so firmly to it that it cannot be washed out again. This is the general method used for dyeing cloth, leather, hair, &c., either black or grey, and for this reason the iron salts, especially green vitriol, have a very extensive application in dyeing and calico-printing.

286. *Nitrate of sesquioxide of iron* ($Fe_2 O_3, 3 \cdot N O_5$) is obtained by adding iron filings to diluted aquafortis, as long as they continue to dissolve in it. Nitric acid furnishes an abundant supply of oxygen to the iron, and this takes up as much oxygen as it can bind, and is converted into a sesquioxide. This solution is of a brown colour, and is used in dyeing. If some aquafortis is dropped upon cast-iron, steel, or bar-iron, black spots are produced, because the iron, but not the carbon, is dissolved. These spots are darker in cast-iron and lighter in bar-iron. Hence, to ascertain how much carbon is contained in a sample of iron, you have only to dissolve a weighed quantity of it in diluted nitric acid, and to weigh the charcoal remaining behind.

287. *Acetate of sesquioxide of iron* may be prepared directly, by dissolving freshly precipitated and still moist hydrated sesquioxide of iron in acetic acid. When the shoemaker pours beer upon iron nails to prepare the iron-black with which he blackens his leather, he obtains acetate of sesquioxide of iron; for, on exposure to the air, the beer is changed into vinegar, and the iron to sesquioxide. Leather is a combination of the skin with tannin; when the latter meets with the sesquioxide of iron, black tannate of iron (ink) is formed. An iron mordant is now frequently prepared for dyeing purposes, by dissolving iron-rust in wood-vinegar (pyrolignite of iron).

288. *Phosphate of the protoxide of iron* is prepared by mixing a solution of green vitriol with a solution of phosphate of soda; the white precipitate produced becomes gradually blue by attracting oxygen from the air (phosphate of the magnetic oxide of iron, blue iron-earth). *Phosphate of the sesquioxide of iron* is white, and occurs in the ashes of many plants.

Iron and Chlorine.

289. *Protochloride of Iron* ($Fe Cl$), a green salt, is formed by dissolving iron in muriatic acid; *sesquichloride of iron* ($Fe_2 Cl_3$), a brown salt, by dissolving sesquioxide of iron or hydrated sesquioxide of iron in muriatic acid, or by the addi-

tion of chlorine water to protochloride of iron. (§ 186.) Protochloride of iron is also called muriate of protoxide of iron, and sesquichloride of iron is often called muriate of sesquioxide of iron.

Iron and Cyanogen.

As chlorine combines with iron, so also cyanogen can form combinations with iron. Two of them, *Prussian blue and yellow prussiate of potassa*, have acquired very great importance in the arts.

290. *Prussian Blue, or Ferrocyanide of Iron* ($3\ Fe\ Cy + 2\ Fe_2\ Cy_3$).

If magnetic oxide of iron is agitated with prussic acid, the black precipitate becomes blue. This insoluble compound is termed *Paris blue;* or, when it is mixed with white substances —for instance, alumina, clay, starch, &c.—*Prussian* or *mineral blue.* Its constitution may be readily imprinted on the memory by regarding it as prussiate of black oxide of iron. It consists, in fact, however, of protocyanide and sesquicyanide of iron, since a haloid salt and water are always formed when a hydrogen acid combines with a metallic oxide. (§ 187.) Both modes of consideration harmonise well with each other, for prussiate of protoxide of iron is the same as cyanide of iron + water,

$$Fe\ O + H\ Cy = Fe\ Cy + H\ O;$$

and prussiate of sesquioxide of iron is the same as sesquicyanide of iron + water,

$$Fe_2\ O_3 + 3\ H\ Cy = Fe_2\ Cy_3 + 3\ H\ O.$$

Prussian blue, on account of its splendid colour, is not only an important article for staining wood, paper, &c., but it is also one of the principal pigments for dyeing cloth, cotton, silk, &c. The colour thus prepared is called, in dyeing establishments, *potassa blue,* to distinguish it from indigo blue. Prussian blue, although it contains prussic acid or cyanogen, is not poisonous. Similar inconsistencies frequently occur in chemical combinations. Sometimes a poisonous combination is formed from innocuous bodies; and sometimes a harmless compound from poisonous constituents. Accordingly, a correct inference cannot always be drawn as to the medical effects of a compound merely from its constituents.

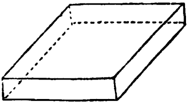
Experiment.—Mix thoroughly together one drachm of Paris blue (pure Prussian blue) and a quarter of a drachm of oxalic acid, with some water; the colour insoluble in water is rendered soluble by the oxalic acid, and a blue liquid is obtained, which, if thickened with gum Arabic, may be used as a blue ink.

Experiment.—If you heat some Prussian blue upon charcoal before the blow-pipe, an empyreumatic odour is produced; the cyanogen is consumed ($C_2\,N$ is converted by the oxygen of the air into $2\,C\,O_2$ and N), and you finally obtain only a brownish-red residue of sesquioxide of iron. Most of the cyanogen compounds are decomposed in a similar manner, by being heated to redness.

291. *Ferrocyanide of Potassium, or Prussiate of Potassa* ($2\,K\,Cy,\ Fe\,Cy + 3\,H\,O$).

Experiment.—Heat to boiling an ounce of finely pulverised Prussian blue with three ounces of water, and as it boils add gradually caustic potassa, until the blue colour of the mixture disappears. You obtain a turbid, brownish-yellow liquid, which you render clear by filtration. What remains upon the filter is hydrated sesquioxide of iron, which is separated by the stronger potassa from the Prussian blue. Tabular crystals are deposited, on cooling, from the clear yellowish liquid; they are commonly called yellow prussiate of potassa, but in chemical language, *ferrocyanide of potassium.* This double salt is formed as follows:

Fig. 142.



Prussian blue: iron with more cyanogen + iron with less cyanogen,
Potassa: oxygen and potassium,
Water: water,

Products: hydrated sesquioxide of iron (Insoluble.) { cyanide of potassium + protocyanide of iron. (Soluble.)

The potassium of the potassa, as we see, replaces the iron in the sesquicyanide of iron, forming cyanide of potassium, which forms a double salt with the remaining undecomposed protocyanide of iron. The oxygen of the potassa passes to the liberated iron, and converts it into sesquioxide of iron. Accordingly, we have in the yellow salt potassium and iron both combined with cyanogen. As water is present, the cyanide of potassium may be regarded also as prussiate of potassa, and the protocyanide of iron as the prussiate of protoxide of iron, and the whole salt as a combination of potassa and protoxide of iron with prussic acid. Such being the case, the prussic acid may be expelled from it by a stronger acid; this, in fact, does take place, for prussic acid is commonly prepared from this salt by adding to it sulphuric or phosphoric acid and some water, and then distilling the mixture.

If blood and potassa lye are boiled together and evaporated to dryness, and the remaining mass is heated to redness, a yellow solution of ferrocyanide of potassium is obtained by the lixiviation of it with water. This salt, prussiate of potassa, must not be confounded with cyanide of potassium, a combination consisting of potassium and cyanogen alone, without iron, and which is a white salt and a *most deadly poison.* The ferrocyanide of potassium (the use of which term instead of prussiate of potassa will prevent the liability of mistaking one compound for the other) is not poisonous.

Ferrocyanide of potassium is prepared on a large scale in a manner similar to that above described. Blood, horn, leather, or other animal substances, are charred; this is best done by dry distillation, in order to obtain ammonia as a secondary product (§ 228); the charcoal thus obtained is then mixed with carbonate of potassa and iron, and the mixture fused at a red heat in a reverberatory furnace. In animal charcoal there is still contained nitrogen. This nitrogen, when heated to redness with a strong base, unites with carbon, forming cyanogen. The cyanogen then enters into combination with the potassium of the carbonate of potassa, which is reduced by means of the charcoal, forming cyanide of potassium. By dissolving the fused mass in water, a portion of the salt gives up its cyanogen to the iron, whereby ferrocyanide of potassium (and caustic potassa) is formed, which, after sufficient evaporation, crystallises from the solution. More recently the hydrogen of the air has been successfully used for the formation of cyanogen, whereby animal substances have become quite superfluous in the preparation of ferrocyanide of potassium.

292. *Experiments with Ferrocyanide of Potassium.*

Experiment a.—By mixing a solution of ferrocyanide of potassium with sulphate of the sesquioxide of iron a deep blue precipitate of Prussian blue is produced; for from

Ferrocyanide of potassium: protocyanide of iron + cyanide of potassium, and
Sulphate of sesquioxide of iron: ——— iron, oxygen, and sulphuric acid,

are ormed $\left\{\begin{array}{l}\text{protocyanide of iron + sesquicyanide of iron}\\ \text{(insoluble), and sulphate of potassa (soluble).}\end{array}\right.$

Experiment b.—Mix a solution of ferrocyanide of potassium with a solution of green vitriol; a light blue precipitate is formed (prussiate of the protoxide of iron and potassa, or ferrocyanide of iron and potassium). Set aside one half of the solution, frequently stirring it; the light colour of the precipitate gradually changes to a darker blue. This change takes place more rapidly by adding to the other portion a few drops of nitric acid, and heating the mixture. In both cases oxidation takes place, whereby a portion of the protoxide is converted into the oxide, so that prussiate of the magnetic oxide of iron or ferrocyanide of iron is formed. Both of the methods here given are employed in the preparation of *Prussian blue* on a large scale. In dyeing, the cloth is first steeped in a solution of iron, and then passed through a slightly acidified solution of ferrocyanide of potassium.

Experiment c.—Add a solution of ferrocyanide of potassium to a very diluted solution of blue vitriol; you obtain a copper-red precipitate of *ferrocyanide of copper*. The copper gives up its oxygen and sulphuric acid to the potassium of the ferrocyanide of potassium, and sulphate of potassa remains dissolved in the liquid. This is the most accurate test for detecting the presence of copper in a liquid. Most of the basic elements, like copper in this instance, form double compounds with protocyanide of iron.

Experiment d.—Sprinkle some ferrocyanide of potassium upon a piece of red-hot sheet-iron, and quench it quickly in cold water; the iron becomes so hard as to resist the action of the file, a coating of steel having been formed on its surface by the carbon of the cyanogen. This simple process is especially adapted for imparting to agricultural implements a greater degree of hardness and durability.

293. *Red prussiate of potassa, or ferricyanide of potassium,* is distinguished from the yellow prussiate by containing sesquicyanide instead of protocyanide of iron. When added to salts of the protoxide of iron it forms a deep blue precipitate (but no

precipitate is produced by it in the salts of the sesquioxide of iron); therefore, it is not only used for producing a blue colour, but also as a reagent to distinguish the salts of the sesquioxide from those of the protoxide of iron.

Iron and Sulphur.

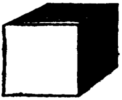
294. *Experiment.—Protosulphuret of Iron* ($Fe\ S$).—On adding some sulphuretted hydrogen water to a slightly acidified solution of green vitriol, no precipitate is produced; but if hydrosulphuret of ammonia is added, a deep black precipitate is formed; this precipitate is *protosulphuret of iron.*

295. *Experiment. — Sesquisulphuret of Iron.* — Twenty grains of sulphur and thirty grains of iron filings are thoroughly mixed and heated upon charcoal by the blow-pipe flame directed upon one part of the mass; this part attains a red heat, which rapidly pervades the whole mass. The yellowish-brown substance obtained is sesquisulphuret of iron. Another method of preparing this substance, and of applying it to the evolution of sulphuretted hydrogen, has been described. (§ 131.) This combination also occurs native (magnetic pyrites).*

Experiment.—If you moisten protosulphuret of iron with water, and let it remain exposed to the air for some weeks, small green crystals will be found disseminated throughout the mass, both the iron and the sulphur having gradually attracted oxygen from the air. $Fe\ S$ is thus converted into $Fe\ O,\ S\ O_3$.

296. *Bisulphuret of Iron* ($Fe\ S_2$).—Iron combined with twice as much sulphur as in the protosulphuret occurs native in many ores, and frequently in common coal, and is called *iron pyrites* or bisulphuret of iron. It has the appearance of brass, and usually occurs in cubic crystals. If heated in a retort, half of the sulphur distils over, and is collected, and black protosulphuret of iron remains behind; accordingly, sulphur may be prepared from it. *Green vitriol* is prepared from this residue, by piling the latter in heaps, and leaving it for several months exposed to the air. The green vitriol thus formed is freed from earthy impurities by lixiviation and evaporation.

Fig. 143.



The salts of iron may be detected by their behaviour before the blow-pipe, by ammonia, tincture of galls, hydrosulphuret of ammonia, and ferrocyanide of potassium.

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* The composition of magnetic pyrites generally corresponds to the formula $Fe_7\ S_8 = 5\ Fe\ S + Fe_2\ S_3$.

Systematic Synopsis of the Compounds of Iron.

Iron.

Carburetted Iron.

a.) Wrought-iron (iron + ½ per cent. of carbon).
b.) Cast-iron (iron + 5 per cent. of carbon).
c.) Steel, a mixture of both.

Sulphurets of Iron.

a.) Protosulphuret of iron, black.
b.) Bisulphuret of iron, yellow.
c.) Sesquisulphuret of iron, brownish-yellow, a mixture of both.

Oxides of Iron.

a.)	Protoxide of iron,	black.
	Hydrated protoxide of iron,	white.
b.)	Sesquioxide of iron,	reddish-brown.
	Hydrated sexquioxide of iron,	yellowish-brown.
c.)	Magnetic oxide of iron,	black.
d.)	Ferric acid (lately discovered).	

Salts of Iron.

a.) Oxygen salts.

Salts of the Protoxide. (Green.)	Salts of the Sesquioxide. (Brown.)
Sulphate of the protoxide of iron.	Sulphate of the sesquioxide of iron.
Nitrate " " "	Nitrate " " "
Carbonate " " "	
Acetate " " "	Acetate " " "
Phosphate " " "	Phosphate " " "

b.) Haloid salts.

Protochloride of iron.	Sesquichloride of iron.
Ferrocyanide of potassium (yellow).	Ferricyanide of potassium (red).
Ferrocyanide of copper (red).	Ferrocyanide of iron (blue).

MANGANESE (Mn).

At. Wt. = 28. — Sp. Gr. = 8.

297. *Black Oxide or Peroxide of Manganese* ($Mn\,O_2$).

Several experiments have already been performed with this mineral, which is chiefly obtained from the Harz Mountains and from Thuringia; we use it especially for the preparation of oxygen and chlorine. It is one of the few combinations of oxygen termed *hyperoxides* or *superoxides;* so called because they contain, as it were, an excess of oxygen, which they give out when heated to redness, or when heated with sulphuric acid. 100 ounces of black oxide of manganese, which contain 36 ounces of oxygen (2 atoms), yield at a moderate heat 9 ounces (½ atom), at an intense red heat 12 ounces (⅔ atom), on heating with sulphuric acid 18 ounces (1 atom), of oxygen. Therefore peroxide of manganese is excellently adapted *for combining other bodies with oxygen*, as was shown in the preparation of chlorine, when the oxygen of the peroxide of manganese oxidised the hydrogen of the muriatic acid, forming water, and thereby liberated the chlorine of the muriatic acid.

Glass-makers often add peroxide of manganese to the fused glass, to render the colour of the black or dark-green bottle-glass yellow or orange, a shade which is generally preferred. In this case, also, an oxidation is effected by the peroxide of manganese. The dark colour of the glass is owing to the protoxide of iron; this obtains oxygen from the peroxide of manganese, and becomes sesquioxide of iron, which colours the fused glass brown or yellow. On this account, black oxide of manganese is called *glass-makers' soap*. If added in *small proportions* to white glass, it gives it a *violet* colour, and in this way artificial amethysts are made.

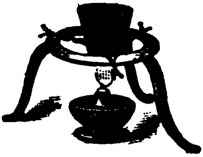
Experiment.—Mix into a thin paste with water one-fourth of a drachm of finely pulverised peroxide of manganese, one drachm of litharge, one of clay, and spread it over a tile. Put the latter between two glowing coals, or direct upon one part of it a strong blow-pipe flame; the mass melts, and forms on cooling a brilliant black coating, or, if less manganese be used, a brown coating. This is the method by which potters prepare their black or brown glaze.

298. *Manganese* (Mn).—By intensely heating the peroxide of manganese with charcoal, all its oxygen may be expelled, and a greyish-white brittle metal (Mn). is obtained, much more difficult of fusion than even iron.

Other Combinations of Manganese.

299. *Experiment.*—Mix in a porcelain crucible a quarter of an ounce of peroxide of manganese with one-eighth of an ounce of sulphuric acid, and expose the mixture to a gentle heat for fifteen minutes, and then to a strong heat for an hour. After cooling, boil the black mass in water, and evaporate the solution to dryness, constantly stirring it when nearly dry; the reddish-white powder is *sulphate of protoxide of manganese* ($MnO, SO_3 +$

Fig. 144.



$4\,H\,O$). Half of the oxygen escaped during the heating, and protoxide of manganese ($Mn\,O$) remains behind, which, being a salt-base, combines with the sulphuric acid. *Muriate of protoxide of manganese*, or protochloride of manganese ($Mn\,Cl$), was formed in the same way during the preparation of chlorine (§ 150), and remained in the flask, having derived a yellow colour from the presence of chloride of iron. Most of the salts of the protoxide of manganese have a reddish colour.

300. Dissolve a portion of the *sulphate of protoxide of manganese* in water, and use the solution for the three following experiments.

Experiment a.—On exposure to the air, the solution acquires a dark-brown colour, and after a time deposits a powder of the same colour, just as occurred in the solution of the sulphate of protoxide of iron. The *protoxide of manganese* attracts oxygen from the air, and is converted into hydrated sesquioxide of manganese, a portion of which separates, sufficient acid not being present to retain all the sesquioxide in solution.

Experiment b.—If some ammonia or potassa is added to another portion of the solution, the stronger bases will take possession of the sulphuric acid, and *hydrated protoxide of manganese* ($Mn\,O + H\,O$) will separate as a white precipitate. On filtering and drying, it will become converted into dark-brown *hydrate of sesquioxide of manganese* ($Mn_2\,O_3 + 3\,H\,O$), precisely as occurred with the hydrated sesquioxide of iron. If a piece of linen, immersed in the solution, is dried, and then passed through a solution of potassa, the precipitate will adhere firmly to the fibres of the cloth, and will acquire, on exposure to the air, a fine dark-brown colour, called by dyers *manganese-brown.*

Experiment c.—Add some sulphuretted hydrogen to a third portion of the solution; no change takes place until some ammonia is added, when a flesh-coloured precipitate is produced, consisting of *manganese* and *sulphur* ($Mn\,S$). In this manner, the presence of manganese in a solution may be ascertained, for manganese is the only metal which, on combining with sulphur, yields a metallic sulphuret of a pink colour. This experiment also affords another example of double elective affinity causing a decomposition which could not be effected by simple elective affinity.

301. *Acids of Manganese.*—Manganese is characterised by

combining with still more oxygen than is already contained in the peroxide.

Experiment.—Mix intimately together in a mortar one drachm of peroxide of manganese and one drachm of caustic potassa; put the mixture in a porcelain crucible, and heat it strongly for half an hour. When cold, add some water to the black mass; you will obtain a green solution, which becomes clear by settling in a test-tube. This green colour is owing to the formation of a salt, which is called *manganate of potassa*, or *chameleon mineral.* By the ignition with potassa, the peroxide of manganese is disposed to receive an additional atom of oxygen from the air, and $Mn\ O_2$ is converted into $Mn\ O_3$, which latter compound comports itself as an acid; that is, it combines with the base present, forming a salt ($K\ O,\ Mn\ O_3$).

Experiment.—Pour half of the green solution into a wine-glass, dilute it with water, and leave it in repose; the green colour soon begins to change, passing through bottle-green and violet to a crimson red, a brown powder (peroxide of manganese) being at the same time deposited. This apparently spontaneous change is occasioned by the carbonic acid of the air, which combines with a portion of the potassa and expels the manganic acid. The manganic acid ($Mn\ O_3$), however, on being deprived of its base, immediately separates into two parts, one of which contains *less* oxygen (peroxide of manganese, $Mn\ O_2$), and the other *more* oxygen (permanganic acid, $Mn_2\ O_7$); $3\ Mn\ O_3$ is converted into $Mn\ O_2$ and $Mn_2\ O_7$. The red colour belongs to the *permanganic* acid, which remains in solution, combined with a portion of the *potassa.*

Experiment.—Add some drops of sulphuric acid to another portion of the green solution, when the change of colour from green to red, that is, the conversion of manganate into permanganate of potassa, will take place instantaneously.

The most remarkable characteristic of these acids is *the facility with which they part with that portion of their oxygen which stamps them as acids.* Even a piece of wood, paper, or any other organic substance thrown into the green or red solutions, decomposes them and removes their colour, and for this reason they should never be filtered through paper. From its singular changes of colour, manganate of potassa has received the name of *mineral chameleon.*

302. Manganese forms with oxygen alone a great variety of combinations.

28 lbs. of manganese or 1 at. Mn	form with " "	8 lbs. of oxygen 1 at. O	Protoxide of manganese, = MnO
28 lbs. of manganese or 1 at. Mn	form with " "	12 lbs. of oxygen 1½ at. O	Sesquioxide of manganese, = Mn_2O_3
28 lbs. of manganese or 1 at. Mn	form with " "	16 lbs. of oxygen 2 at. O	Peroxide of manganese, = MnO_2
28 lbs. of manganese or 1 at. Mn.	form with " "	24 lbs. of oxygen 3 at. O	Manganic acid, = MnO_3
28 lbs. of manganese of 1 at. Mn.	form with " "	28 lbs. of oxygen 3½ at. O	Permanganic acid, = Mn_2O_7

It is, moreover, hereby rendered very obvious, that it is the *quantity* of the oxygen which makes one and the same element sometimes a *base*, sometimes an *acid*. Some idea may be formed of the great army of salts which manganese alone, in virtue of this double character, can call into the field, when we reflect that it not only combines with all the acids, forming protoxides and sesquioxides, but also with all the bases, forming manganates and permanganates.

COBALT (Co) AND NICKEL (Ni).

At. Wt. = 30.—Sp. Gr. = 8.5. At. Wt. = 30.—Sp. Gr. = 9.

303. During the Middle Ages, when the miner held intercourse with earth-spirits and goblins in the solitary depths of his mines, ores were occasionally found, particularly in the mines of Schneeberg, in Saxony, resembling in brilliancy and weight the finest silver ores, which, however, yielded in the smelting furnaces no silver, but crumbled away to a grey ash, a disagreeable odour of garlic being at the same time emitted. In accordance with the superstitious notions of those times, the miner attributed the disappearance of the supposed silver to the malicious jests of the earth-spirits, and contemptuously rejected these ores, which he baptised by the names,—cobalt and nickel. But now they are held in high estimation, cobalt being used for imparting a beautiful blue colour to glass and porcelain, and nickel for giving to brass the appearance of silver. As these metals are melted only with great difficulty, the heat of the old furnaces was not sufficient to fuse them. The odour of garlic was occasioned by the arsenic, which always accompanies the ores of cobalt and nickel.

304. *Smalt, Azure, or Cobalt-blue.*—The ores (white cobalt,

cobalt pyrites, cobalt glance, &c.), containing arsenical cobalt and nickel, are now worked in the following manner. The stamped ores are first roasted in a reverberatory furnace, to expel any arsenic that may be present, and to convert the cobalt into oxide of cobalt; then it is mixed with sand and carbonate of potash, and the mixture fused in clay crucibles. Thus a glass is produced, in which the oxide of cobalt dissolves, imparting to it a deep blue colour; but the arsenical nickel, together with any silver and bismuth present, collects at the bottom of the crucible as a fused metallic lump (*speiss*). The melted blue glass is rendered brittle and friable by pouring it into cold water, after which it is ground to an impalpable powder, and elutriated. It is much used, under the name of *smalt* and *azure*, not only as a vitrifiable pigment for glass, porcelain, and pottery, but for colouring paper, and also in washing, for giving a blue tint to linen and muslin.

305. *White Copper, or German Silver.*—The speiss, which remains after the fusion of the cobalt ore, is now generally used in the preparation of *German silver*. The arsenic is first expelled, the bismuth and silver are then removed, and the nickel is then melted with from four to five times as much brass (copper and zinc), whereby a metallic mixture (an alloy) of a silvery-white colour, beautiful brilliancy, and great malleability, is obtained. This alloy is extensively used, as a substitute for silver, in the manufacture of a great variety of articles, not only of convenience, but of luxury.

306. As pure metals, *cobalt* and *nickel* have a great similarity to iron, both in their external appearance and in their combinations ; but they are nobler metals, that is, they do not attract oxygen with such avidity, and they do not rust so readily as iron. The three metals, iron, cobalt, and nickel, constitute, as has been already mentioned, the *magnetic trio* ; they alone, of all the metals, are attracted by the magnet. It is, moreover, remarkable, that just these three metals always occur in meteorites, which occasionally fall to the earth, we know not whence, in a glowing state (meteoric iron, meteoric stones).

307. Both of these metals, like iron, form with *oxygen* a protoxide and sesquioxide.

Protoxide of cobalt ($Co\,O$) is of an olive-green colour, and its *hydrate* is pink; *sesquioxide of cobalt* ($Co_2\,O_3$) is black.

These oxides are frequently employed in painting on porcelain and glass.

Protoxide of nickel (Ni O) is of a greenish-grey, and its *hydrate* of a beautiful apple-green colour; *sesquioxide of nickel* ($Ni_2 O_3$) is black. Chrysoprase, known as an ornamental stone, is quartz, coloured green by protoxide of nickel.

308. The *salts of the protoxide of cobalt* are of a pink colour. A solution of the *nitrate of the protoxide of cobalt* is often used in blow-pipe experiments, especially for the detection of alumina (§ 262); a solution of *protochloride of cobalt* is employed as a sympathetic ink, as it possesses the property of becoming blue by evaporating the water, and again pink on absorbing water. Cobalt forms, with phosphoric and arsenious acids, red insoluble compounds, which are now employed as vitrifiable pigments in glass and porcelain painting. The *salts of protoxide of nickel* have a light-green colour.

The salts of cobalt and nickel, like those of iron, are not precipitated by sulphuretted hydrogen, but they are by hydrosulphuret of ammonia, as black *sulphurets of cobalt* and *nickel.*

ZINC (Zn).

At. Wt. = 32.—Sp. Gr. = 6.8.

309. Not very long ago, zinc was hardly used except for making brass and pinchbeck; but since the art of rolling it out into sheets, of forging it, and of drawing it out into wire, has been acquired, it is used also for the manufacture of many articles which were formerly made of lead, copper, and iron; for instance, for making nails, gasometers, gas-pipes, gutters, and for roofs of houses, for lining refrigerators, &c., as it is harder, and yet lighter than lead, cheaper than copper, and less liable than iron to be destroyed by air and water. It usually occurs in commerce in the form of plates, which are so brittle, that they may be broken by the hammer into small pieces; the fresh fracture exhibits a *hackly** crystalline structure, and a bluish-white colour.

310. *Experiments with Zinc.*

Experiment a.—When polished zinc remains exposed to the air for some time, it loses its lustre, and is covered with a grey film. This film consists of zinc combined with a small quantity of oxygen, and is called *suboxide* of zinc.

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* "*Hackly fracture;* when the elevations are sharp or jagged, as in broken iron."—Dana's *Manual of Mineralogy.*

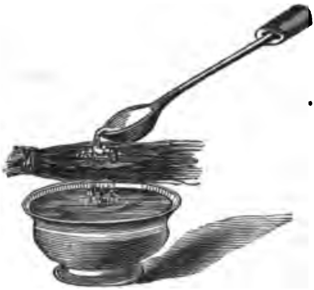
Experiment b.—If a piece of polished sheet zinc be alternately exposed to the action of water and of air, it will become gradually covered with a white film; it rusts like iron, but the rust of zinc has a white colour. In iron the oxidation proceeds rapidly towards the interior, but not in zinc, or only very slowly; therefore articles made of zinc, when exposed to the wind and weather, last much better than those made of iron, and for this reason, also, iron articles are frequently coated with zinc (galvanised iron). Iron-rust is hydrated sesquioxide of iron, zinc-rust is hydrated oxide of zinc. Zinc attracts not only oxygen, but also some carbonic acid, from the air, and this may be recognised by the effervescence which follows when some acid is dropped upon the rusted zinc; consequently, the white film is a double compound of hydrated oxide of zinc with carbonate of the oxide of zinc (*basic carbonate of the hydrated oxide of zinc*).

Experiment c.—Hold a piece of zinc by means of a pair of tongs or pincers in the alcohol-flame, until it hisses if you touch it with a piece of moist wood; if you now quickly hammer it upon a stone or anvil previously heated, it does not break, but spreads out like lead into a thin, coherent sheet. Zinc has the singular property *of being ductile between* 212° F. (100° C.) *and* 302° F. (150° C.), but *below or above this temperature it is brittle.* Ever since it has been known that zinc is thus affected by heat, it has been found easy to overcome the difficulties which formerly opposed the conversion of this metal (which is unpliant when cold) into sheets and wire.

Experiment d.—Zinc, when heated to about 752° F. (400° C.), *melts*, as may easily be seen by holding a small piece of it in an iron spoon over an alcohol flame. In this case a grey film of suboxide is likewise formed; but this after a time assumes a yellow colour, and is converted into oxide ($Zn\ O$). On cooling, the yellow colour passes to white; the oxide of zinc belongs to those substances which present a colour in the heat different from the colour at the ordinary temperature.

Experiment e.—In chemical experiments, especially for the evolution of hydrogen, it is very convenient to use zinc in the

Fig. 145.



form of small grains (granulated). It is very easily obtained in this state, by pouring the melted metal through a moistened broom, gently shaking it while it is held over a basin of water. In this way the other easily fusible metals also, such as lead, tin, bismuth, &c., may be subivided into smaller parts, and with much more facility than by filing or cutting.

Experiment f.—At a still stronger heat, zinc *evaporates*, and *burns* at the same time, with a bluish flame. In this experiment the spoon containing the zinc must be placed on red-hot coals, that it may become hotter than by the spirit-lamp. A beautiful appearance is presented, even on a small scale, by heating a piece of zinc upon charcoal, before the blow-pipe; the metal is soon converted into a loose, spongy mass of oxide, and during the combustion, blue flames burst forth from the oxidised coating. The oxide is *not volatile*, for if it were, nothing at all would remain behind. The flame is caused by the burning fumes of zinc; the substance formed by the combustion is oxide of zinc. This is called *oxide prepared in the dry way*, or *flowers of zinc*, and it may be freed from any admixture of metallic particles by elutriation. Zinc has only this *one* degree of oxidation.

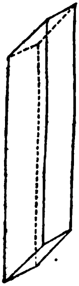
Zinc and Acids.

311. All *diluted acids* readily dissolve zinc, with the evolution of hydrogen, and form with the oxide produced *salts of zinc*. The hydrogen liberated in this way is much purer than that prepared with iron; on this account, zinc is generally employed in the preparation of hydrogen, namely, for Dobereiner's hydrogen-lamp, balloons, &c. If, as is usually done, diluted sulphuric acid is taken for dissolving the zinc, we obtain on evaporation the best known of the salts of zinc, the sulphate of the oxide of zinc.

312. *White Vitriol, or Sulphate of Oxide of Zinc* ($Zn\,O,\ S\,O_3 + 7\,H\,O$).

This salt crystallises in colourless, rhombic prisms, which contain nearly half their weight of water of crystallisation. Sulphate of the oxide of zinc, called also white vitriol, is easily soluble in water, and is often employed as a cooling application, particularly in inflammation of the eyes. Tolerably large quantities of this salt may be prepared without much trouble, by evaporating the waste liquids left after generating hydrogen from zinc and sulphuric acid. The black substance which deposits from the solution of zinc is for the most part charcoal, a little of which always unites with zinc on the smelting of it from its ores. As it is not soluble in acids, it must remain behind on dissolving the metal.

Fig. 146.



All the salts of zinc are *poisonous*, and excite, when introduced into the stomach, violent vomiting; milk, white of eggs, and coffee, are employed as antidotes.

Experiments with White Vitriol.

a.) Prepare a solution of white vitriol, and add to it *ammonia* or *potassa*. A white precipitate of *hydrated oxide of zinc* is formed, which dissolves again in an excess of the alkali.

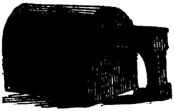
b.) *Hydrosulphuret of ammonia;* here also a white precipitate is produced; this is *sulphuret of zinc.* This behaviour of zinc is taken advantage of to distinguish and to separate it from other metals. Sulphuret of zinc also occurs native, but then it has a red or a brown colour, and is called *zinc blende.* From this ore, by roasting, weathering, and lixiviation, white vitriol is prepared, precisely in the same manner as green vitriol is obtained from sulphuret of iron.

c.) *Carbonate of soda; carbonate of the hydrated oxide of zinc* is obtained likewise in the form of a white precipitate. If this is dried, after having been previously washed with water, full one half of the carbonic acid passes off; when heated to redness, all the carbonic acid escapes and the *oxide of zinc* remains behind. The oxide thus prepared is called *oxide of zinc prepared in the moist way.*

313. Carbonate of zinc occurs also in nature most abundantly, in Silesia, Westphalia, and Belgium; it is the most important zinc ore, and metallic zinc is generally prepared from it in the above-mentioned places. The miner calls this ore *calamine*.

314. *Preparation of Zinc.*—In order to convert the calamine into metallic zinc, the carbonic acid and oxygen must be expelled. The first is effected in the same way as with carbonate of lime, by calcination in furnaces, and the latter in the same way as with the iron ores, by heating to redness with charcoal. But the process of reduction cannot be conducted in open furnaces, for in them the reduced zinc would evaporate and burn up in the air, forming again oxide of zinc, so that from oxide of zinc in the furnace we should only obtain oxide of zinc in the air. It is rather a process of *distillation* than of melting that we must undertake. Clay cylinders or muffles are employed for conducting the distillation. Several of these are ranged in circles, or are piled one above the other in a furnace. The annexed figure is a representation of a muffle. At one end of it is a curved projection made of clay, through which the two gaseous substances, carbonic acid gas and vapour of zinc, formed during the heating of the roasted ore with charcoal, may escape. The zinc condenses mostly in the tube, and drops, in the metallic state, into a vessel containing water. This is again to be melted and cast into sheets. The zinc of commerce always contains an admixture of small quantities of iron and lead. If the amount of lead is more than one and a half per cent., then the zinc remains brittle even when heated, and cannot be rolled out into sheets.

Fig. 147.



CADMIUM (Cd).

At. Wt. = 56.—Sp. Gr. = 8.6.

315. *Cadmium* is a rare metal, and may be regarded as the twin brother of zinc, in the ores of which it is found in small quantities. It is chiefly distinguished from zinc by its malleability when cold, and by being precipitated from its solution by sulphuretted hydrogen as *yellow sulphuret of cadmium*. As already mentioned, this reagent gives no precipitate with the salts of zinc, but the latter is thrown down by sulphuret of ammonium, as *white sulphuret of zinc*.

TIN, STANNUM (Sn).

At. Wt. = 59.—Sp. Gr. = 7.2.

316. *Tin* is one of the few metals which were known in the most ancient times. It becomes fluid at a very moderate heat, at 446° F., and in many countries its ores are found in the sand with which the surface of the soil is covered; therefore it was easily obtained and easily smelted. Formerly it was obtained principally from the British Islands, which were, therefore, called also Tin Islands, and even at the present time they, together with Malacca in the East Indies, furnish the purest tin. The properties which especially characterise tin, and render it a very valuable metal, are its beautiful lustre, and its great softness and flexibility,—its slight affinity for oxygen, in consequence of which it long retains its brightness in the air and in water,—its easy fusibility, which renders it peculiarly well adapted for casting, and for coating other metals (*tinning*). It has, indeed, lost much of its earlier importance as a material for making many vessels of domestic use, such as dishes, cans, &c., since such articles are now handsomely and cheaply manufactured from glass and porcelain. But it is now applied in the arts and trades in a variety of ways not formerly in use. In the older works on chemistry, it is called *Jupiter*, and has the symbol ♃.

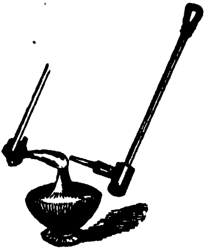
317. *Experiments with Tin.*

Experiment.—Heat a piece of tin upon charcoal before the blow-pipe; it will soon become covered with a powder, of a yellow colour when hot, but white when cold; this is *peroxide of tin*, a combination of one atom of tin with two atoms of oxygen ($Sn\ O_2$). Peroxide of tin thus obtained is *not* soluble in *any acid*, and cannot be fused by the strongest heat. It is so fine a powder, that it is often used for polishing glass and metals.

Tin also occurs native as an insoluble oxide, either crystallised (crystals of tin ore), or scattered through various kinds of rocks (tin stone of Saxony and Bohemia), or, finally, as an ingredient of the sand or *débris* of low grounds in many countries (wood-tin in England). Oxide of tin is the only ore from which tin is largely extracted; its most common admixtures are iron and arsenic.

Experiment.—Place two grains of tin and eight grains of lead on charcoal, and heat them before the blow-pipe; they melt and combine most intimately with each other; an alloy of tin and lead is obtained. If this is heated to redness, the oxidation proceeds so rapidly, that the mass takes on a lively motion, and continues to glow even when it is removed from the fire. In this manner the potter prepares the porcelain-like glaze for earthen baking-pans, and for Delft ware. Add some powdered borax to this mixture of oxides of lead and tin, and form with it a bead upon platinum wire; the bead is not transparent, but, owing to the presence of the infusible peroxide of tin, is opaque, and looks like porcelain (enamel).

Fig. 148.



318. *Alloys* of tin and lead are generally used by workers in metal, under the name of *solder*, for joining metals together (soft soldering). Solder is to the tinman what glue is to the carpenter. An alloy of two parts of tin and one part of lead is the most easily fusible, and is called *fine solder.* Another alloy, used in the soldering of coarser articles, such as gutters, is composed of two parts of lead and one part of tin, and is called *coarse solder;* it is so thick that it does not spread itself, but must be applied by smearing. For soldering those metallic articles which are to be subjected to a stronger heat, brass, or some other alloy of difficult fusibility, is made use of *(hard solder or brazing)*.

Some lead is added even to the tin of which the tinman makes his articles, because pure tin is somewhat brittle, and does not adapt itself well to the moulds. The quantity of lead which can be added to tin is in many countries regulated by law ($\frac{1}{9}$ to $\frac{1}{6}$). Such an alloy is called *proof tin*, to distinguish it from refined or grain tin, which is tin in its greatest purity. If an acid be poured on proof tin, the tin only is dissolved; tin has, accordingly, the power of protecting lead from the attacks of acids.

Tin and Muriatic Acid.

319. The most important solvent of tin is *muriatic acid;* the two most important salts of tin, protochloride and perchloride of tin, are prepared by means of it.

Protochloride of Tin.—*Experiment.*—Place in two porcelain dishes or earthenware pots some tinfoil, and then add some muriatic acid to one of the portions. After some hours pour this acid upon the tin in the second vessel, and then again into the first vessel, repeating the process so that the metal may come in contact for some days alternately with the air and the muriatic acid. Protoxide of tin is formed by the oxygen of the air; it is dissolved by the acid. We thus obtain a solution of the *muriate of protoxide of tin*, or *protochloride of tin*, from which, on evaporation and cooling, colourless rhomboidal prisms are deposited. In commerce this salt is called *salt of tin.* It possesses, in common with the salts of protoxide of iron, the property of attracting with great avidity still more oxygen from the air, and changing into the peroxide salt. Thus is explained why the salt of tin, which has been for some time exposed to the air, no longer presents a clear, but a milky, solution. To obtain a clear solution, muriatic acid must be added, which combines with the precipitated protoxide of tin.

320. *Protoxide of Tin* ($Sn\,O$).—*Experiment.*—Pour some ammonia upon a solution of salt of tin; the white precipitate which is formed is hydrated *protoxide of tin.* By boiling the solution, the combination of the protoxide and water is destroyed, and an anhydrous protoxide of tin is formed, which has a dark-green colour, and must be quickly washed with boiled water and dried, as it likewise attracts more oxygen from the air. If you heat the dried protoxide before the blow-pipe, it burns with great briskness, like tinder, forming peroxide of tin.

321. *Perchloride of Tin* ($Sn\,Cl_2$).—*Experiment.* — Add chlorine water to a solution of salt of tin, until the odour of chlorine is no longer destroyed. $Sn\,Cl$ is thereby converted into $Sn\,Cl_2$, or *perchloride of tin.* This combination can also be obtained by boiling a solution of salt of tin in a mixture of muriatic acid and nitric acid, or by dissolving tin in aqua regia. The dyers call this liquid permuriate of tin, tin mordant, or red spirits. By the addition of ammonia, *peroxide of tin* is obtained, which is distinguished from that formed at § 317 by its dissolving *very easily* in acids.

Protoxide and peroxide of tin dissolve also in potassa lye, and comport themselves, like alumina (§ 260), as acids towards strong bases.

322. *Experiment.*—If a few drops of a solution of gold are added to a very dilute solution of protochloride of tin, a purple-red precipitate is formed (but not in a solution of perchloride of tin), which is called *purple of Cassius* or *gold purple*, and is one of the most important vitrifiable pigments, because it produces, when fused into glass or porcelain, the most superb purple-red colour. Solution of gold is a good test for the salts of the protoxide of tin.

323. *Experiment.*—Mix a decoction of Brazil-wood with protochloride or perchloride of tin; the yellowish-red colour of the liquid is converted into a beautiful crimson-red. Similar advantageous changes of colour are also effected by these salts in other colouring matters, and on this account they are very frequently used as so-called *mordants* in dyeing and calico-printing.

Tin and Nitric Acid.

324. *Experiment.*—Heat some grains of tin with nitric acid in a test-tube; the tin is converted, under a brisk evolution of yellow fumes, into a white powder, *peroxide* of tin. The nitric acid will, perhaps, convert the tin into an oxide, but it *cannot* combine with the oxide produced. The peroxide of tin thus obtained combines, indeed, with other acids, but *not so completely* as that obtained according to § 321; that prepared by heating does not *at all* unite with them, as has been already stated. (§ 317.) Peroxide of tin accordingly occurs in three isomeric states: namely, the insoluble, the very easily soluble, and the difficultly soluble, in acids.

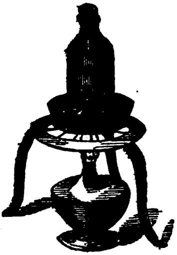
Tin and Sulphur.

325. *Experiment.*—Sulphuretted hydrogen water produces, in a solution of protochloride of tin, a reddish-brown precipitate of *protosulphuret of tin* (Sn S), and in a solution of perchloride of tin a yellow precipitate of *bisulphuret of tin* ($Sn\ S_2$). It is obvious that in the first case one atom of chlorine is replaced by one atom of sulphur, and in the latter case two atoms of chlorine by two atoms of sulphur.

Protosulphuret of Tin (Sn S).—*Experiment.*—Both these metallic sulphurets may be prepared in the dry way. Envelop 12 grains of flowers of sulphur in a piece of tinfoil, weighing 24 grains, then roll up the packet so that it may be introduced into a test-tube, and heat it; half of the sulphur burns, but the other half, under a lively glowing, combines with the tin, forming a brownish-black mass of a metallic lustre (Sn S). If you sprinkle the tube, while still hot, with water, it is rendered friable, and can easily be separated from the fused protosulphuret of tin. The weight of the latter amounts to nearly thirty grains.

Bisulphuret of Tin ($Sn\ S_2$).—*Experiment.*—Pulverise the thirty grains of protosulphuret of tin thus obtained, and mix the powder intimately with six grains of sulphur and twelve grains of sal ammoniac; put the mixture into a thin-bottomed glass flask of an ounce capacity, and heat it for an hour and a half in a sand-bath. You obtain bisulphuret of tin; but in this case, as a mass having a golden lustre, and to which the name *aurum musivum*, or *mosaic gold*, has been given. It may be used for giving a gold-like coating to wood, plaster of Paris, clay, &c. (*bronzing*). The sal ammoniac is found again as a sublimate in the upper portion of the flask; it promotes the formation of a beautiful gold colour, without itself undergoing or producing any chemical change.

Fig. 149.

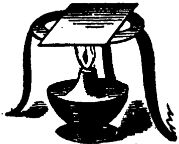


326. *Preparation of Tin.*—Tin is prepared in smelting-houses, in a very simple manner, from tin-stone (peroxide of tin). The finely-stamped ore is first roasted, by which process the arsenic is volatilised and the iron oxidised. Then it is washed or elutriated with water, whereby the lighter particles of stone (the *gangue*), and, to a great extent also, the oxide of iron, are washed away. Finally, it is fused with charcoal in a blast-furnace, and carbonic oxide gas and metallic tin are obtained, the latter of which flows off below. The Saxony tin is usually cast in thin sheets, and the English tin in slender bars. Most of the tin of commerce contains traces of arsenic and other metals. A bar of tin emits a grating sound on being bent, and by repeating the operation several times in succession, it becomes very hot; the reason is, that the tin, on hardening, assumes a crystalline texture, and these crystalline particles are displaced by the bending, and rub against each other. These

crystals may be very beautifully produced upon tinned-iron sheets.

Experiment.—Heat a piece of tin-plate (tinned-iron plate) upon a tripod, over a spirit-lamp, till the tin is melted; then quench it with water, that the tin may harden quickly. The surface of the plate has a dull grey aspect, for it is covered with a film of oxide; but the most beautiful crystalline figures will very soon appear upon it by rubbing it alternately with balls of paper, one of which is moistened with diluted aqua regia, and the other with potassa lye. Both these liquids dissolve the coating of oxide, and lay bare the pure metallic tin surface (*moiré métallique*).

Fig. 150.



327. *Tinning.*—*Experiment.*—The method of coating copper or brass with tin has already been described. (§ 229.) This may be done also in the moist way, by heating to the boiling point finely cut up tinfoil, or tin scrapings, in a pot with cream of tartar and water, and then boiling for half an hour in this liquid some brightly-polished copper or brass articles; as, for instance, farthings and brass nails. The free acid of the cream of tartar effects a solution of some of the tin, and on longer boiling this tin will again separate in the metallic state upon the more electro-positive copper or brass, as in § 284. In this manner pins are tinned or whitened.

Experiment.—Let some vinegar stand over night in a vessel of tin-plate, and then test it with a solution of gold; the purplish colour which forms indicates that even the weak vinegar can dissolve tin. Tin is not, indeed, so poisonous as lead or copper, but yet it is injurious to health; therefore, acid food and drinks should not be allowed to stand for any length of time in tin or in tinned vessels.

Spurious silver-leaf is made of an alloy of tin and zinc, which is hammered out into extremely thin leaves.

URANIUM (U).

At. Wt. = 60.—Sp. Gr. = ?

328. *Uranium* is one of the rarer metals, and occurs in combination with oxygen in a black mineral called pitch-

blende, found in Saxony. From it is prepared the uranate of ammonia, a beautiful yellow powder, known in commerce under the name of *oxide of uranium.* At a white heat it is reduced to black protoxide, and yields a very permanent black pigment for painting on porcelain. The yellowish-green (may-green) glass, now so popular, likewise owes its colour to the oxide of uranium.

The following metals, *Cerium, Lanthanium, and Didymium,* are mentioned here only by name, as chemical rarities.

RETROSPECT OF THE FIRST GROUP OF HEAVY METALS.

1. The metals hitherto considered possess the property of decomposing water, when they are heated to redness, or in the presence of an acid (water-decomposing metals); therefore *diluted* acids are employed for dissolving them.

2. At their lowest degrees of oxidation, they are strong bases.

3. None of these metals are found pure in nature; they most frequently occur as *oxides,* consequently combined with *oxygen.*

4. The specific gravity of these metals is from 6.6 to 8.8.

5. Iron, manganese, zinc, cobalt, and nickel, are *not* precipitated as sulphurets from their acid solutions by sulphuretted hydrogen, but only by hydrosulphuret of ammonia (all the other heavy metals are converted by *either* of the solutions into sulphurets). This fact is made available in analytical chemistry, as an important means of separating the above-named (electro-positive) from the other (electro-negative) metals.

SECOND GROUP OF HEAVY METALS.

LEAD, PLUMBUM (Pb).

At. Wt. = 104.—Sp. Gr. = 11.5.

329. Next to iron, *lead* is the most widely diffused and the cheapest metal; it is, at the same time, also very useful, not merely because we cast shot and types from it, and construct sulphuric-acid chambers of it, but also on account of the many useful combinations which it forms with oxygen and the acids. This metal appears as an enemy to human health, not, however, openly, but under the mask of friendship; for it conceals its noxious effects behind a sweet taste, which is peculiar to

most of its combinations. These effects, moreover, do not manifest themselves immediately when the lead enters the system; it is often only after the lapse of years that they appear (lead colic). It is, for this reason, classed among the *slow poisons.* Perhaps, also, this was the reason why it was formerly compared with the god of time, and received the name of Saturn, and the sign ♄. The external properties of lead, its lustre, its easy fusibility, its softness and pliability, its high specific gravity, &c., are well known; therefore we shall proceed at once to the consideration of its internal or chemical character.

Experiments with Lead.

330. *Experiment.*—Pour into one glass distilled water, into another spring-water, and place in each a piece of lead; the distilled water soon becomes turbid, and reacts basically, but not so the spring-water. Pure water readily attacks lead, and converts it into hydrated oxide of lead; in spring-water, on the contrary, there is formed in time, by the sulphates almost always present in it, some insoluble sulphate of lead, which forms a firm coating upon the metallic lead. This explains the harmlessness of leaden pumps, which, in many countries, are very generally used instead of wooden pumps.

331. *Experiment.*—If lead is heated before the blow-pipe in the exterior flame, it melts at about 608° F. (320° C.), and is thereby coated with a grey film; indeed, it is finally entirely converted into a grey powder. This may be regarded either as suboxide of lead, or as a mixture of oxide of lead with metallic lead. By continued blowing, this grey colour is changed to yellow; the yellow body is *protoxide of lead* (PbO). At a stronger heat the oxide melts, and solidifies on cooling into a reddish-yellow mass, composed of brilliant scales, the well-known *litharge.* By directing upon it the *inner* blow-pipe flame, metallic lead will again be obtained. This easy reducibleness, which is peculiar to almost all salts of lead, together with the *incrustation of yellow oxide, deposited upon the charcoal,* is a certain test for the presence of lead.

Protoxide of lead contains, for every 104 pounds of lead, 8 pounds of oxygen, or one atom of lead and one atom of oxygen; lead, consequently, is one of those chemically feeble bodies which have a very high atomic weight, since 104 pounds of it is able to accomplish only as much as 28 pounds of iron, or 32 pounds of zinc. Protoxide of lead in the form of *litharge* has a very great application in the arts and trades. How lead-glass (flint-glass), lead-glaze, and sugar of lead are prepared from it, has already been described; the manufacturing chemist likewise prepares from it red lead, white lead, and other lead colours, and lead salts; the apothecary compounds insoluble soap (lead plaster), by boiling it with olive-oil; the cabinet-maker makes a varnish that dries rapidly, by boiling it with linseed oil, &c. The English litharge is esteemed the purest; that of Saxony and Goslar always contains small quantities of oxides of copper and iron, perhaps also a little silver. The preparation of it on a large scale will be described under silver. By melting litharge in a Hessian crucible, a brownish-yellow transparent glass is obtained on cooling; this consists of oxide of lead combined with some silicic acid. The silicic acid came from the crucible.

332. *Red Oxide of Lead.—Experiment.*—Heat in a ladle one drachm of litharge and a quarter of a drachm of chlorate of potassa; the yellowish mixture smoulders to a red powder, which must be well washed with water. The same thing happens on heating the litharge for a day, but not to the melting point; and at the same time frequently stirring it. In both cases the litharge receives one-third more of oxygen; in the former case from the chloric acid, in the second case from the air; and is thereby converted into $Pb_3\,O_4$; this compound is called *red lead*, or *minium*, and is much used as a scarlet pigment.

333. *Peroxide of Lead* ($Pb\,O_2$).—*Experiment.*—If you heat some red lead gently in nitric acid for a few minutes, it is resolved into an oxide, which dissolves, and into *peroxide* ($Pb\,O_2$), which remains undissolved as a dark-brown powder. Lead is one of the few metals which combine with oxygen, forming superoxides.

Lead and Acids.

334. The best solvent of lead is nitric acid. Sulphuric, phosphoric, and muriatic acids *cannot* dissolve lead, because they form with it insoluble, or very difficultly soluble salts. As protoxide of lead is easily made, the most advantageous method of preparing the salts of lead is by dissolving the protoxide in acids, because that portion of the acid is thereby saved which would otherwise have been required for the conversion of the lead into the oxide of lead.

Nitrate of Lead ($Pb\,O, N\,O_5$) has already been prepared in two ways. (§ 160.)

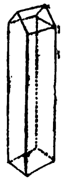
335. *Sulphate of Lead* ($Pb\,O, S\,O_3$). (§ 173.)—This salt is easily formed by simple or double elective affinity, when sulphuric acid or sulphate of soda is added to a solution of lead. Even in a solution of lead more than a thousand times diluted, a white turbidness is produced, since the sulphate of lead is an entirely insoluble salt; we have, accordingly, in sulphuric acid, a very delicate test for salts of lead. This salt is obtained in great quantities in print-works, as a secondary product in the preparation of the acetate of alumina (*alum mordant*) from sugar of lead and alum. (§ 262.)

336. *Chloride of Lead* (Pb, Cl).—*Experiment.*—Heat to boiling one drachm of litharge, with half an ounce of muriatic acid and half an ounce of water, and decant the clear liquid from the sediment into a glass vessel; you obtain, on cooling, lustrous white acicular crystals of chloride of lead (horn-lead). This salt is but very sparingly soluble in water.

Experiment.—If two grains of litharge and fifteen grains of sal ammoniac are fused together in an iron spoon, there is obtained a combination of a small quantity of chloride of lead, with a large proportion of oxide of lead, in the form of a brilliant, yellow, laminated mass, which when triturated yields a handsome yellow powder. This powder is used by painters under the name of *Cassel* or *mineral yellow.*

337. *Acetate of Oxide of Lead* ($Pb\,O, \bar{A} + 3\,H\,O$), combined with one-seventh of its weight of water of crystallisation, forms the most important soluble salt of lead, *sugar of lead* (§ 198), which commonly crystallises in four-sided prisms. On exposure to the air, some of its acetic acid is driven off by the carbonic acid of the air, and the salt then yields with water a turbid solution, but which may be rendered transparent by adding to it a few drops of acetic acid.

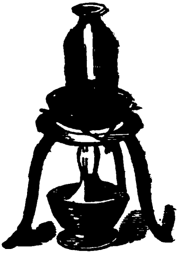
Fig. 151.



Basic Acetate of Oxide of Lead is prepared by digesting a solution of sugar of lead with oxide of lead, whereby part of the oxide of lead is dissolved. This combination is kept in the apothecaries' shops in a liquid form, under the name of *solution of subacetate of lead*, or *Goulard's extract.* When mixed with spring-water it forms the so-called *Goulard water*, which has a milky appearance, because some carbonate of lead is formed and separated by the carbonic acid of the water.

338. *Tartrate of Oxide of Lead.—Experiment.*—Mix a solution of two grains and a half of sugar of lead with a solution of one grain of tartaric acid; the white precipitate formed is collected on a filter, washed, and dried; it is insoluble *tartrate of lead.*

Fig. 152.



Experiment.—Fill a small phial one-third full of dry tartrate of lead, and heat it in a sand-bath over a spirit-lamp, as long as fumes continue to escape. These have an empyreumatic odour, and burn with a blue flame, because they contain much carbonic oxide gas, which is generated by the carbonisation of the tartaric acid. But the tartaric acid contains so much carbon, that a portion of it remains behind, intimately mixed with the metallic lead. The black substance obtained is a *pyrophorus,* which inflames spontaneously when poured out upon a stone, because, on account of its great porosity, it imbibes oxygen eagerly from the air. The yellow powder produced by the ignition is oxide of lead. If the phial is closed while it is yet hot, this pyrophorus will retain its inflammability for several days.

Hydrate of Oxide of Lead.—Experiment.—By adding ammonia to a solution of sugar of lead as long as a precipitate forms, hydrate of oxide of lead is obtained as a white powder. It is converted by heating into yellow anhydrous oxide of lead.

339. *Carbonate of the Oxide of Lead* ($Pb\ O,\ C\ O_2$).

Add to a solution of sugar of lead a solution of carbonate of soda, as long as a precipitate is formed; the precipitate is carbonate of oxide of lead. The pigment known under the name of *white lead* is likewise carbonate of lead, but mixed with variable quantities of hydrated oxide of lead (basic carbonate of lead). This is prepared on a large scale in different ways.

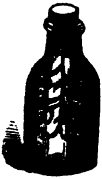
a. According to the *English method,* litharge is mixed with vinegar to form a paste; this is then spread upon a stone slab, and exposed to the fumes of burning coke, the carbonic acid of which combines with the oxide of lead. The acetic acid acts in this case the part of a mediator. Like the nitric oxide in the sulphuric-acid chambers, it dissolves the oxide of lead, and then tenders it to the carbonic acid; when it has given up the first portion, it dissolves a second, &c. It is obvious that in this way a small quantity of acetic acid (or else of sugar of lead) is sufficient to aid in converting gradually a large quantity of litharge into white lead.

b. By the oldest, the *Dutch method*, a large number of jars, in which some vinegar has been poured, are arranged in a building upon a layer of stable-manure or tan, and rolls of sheet-lead are then suspended in the jars above the vinegar, and the whole covered with another layer of stable-manure. After the lapse of several months, the rolls of lead are found to be mostly, if not entirely, converted into white lead. The manure is decaying straw, tan is decaying wood; decay is a slow combustion, or, what is the same thing, a slow conversion of organic substances into carbonic acid and water. In every combustion or decay, heat is liberated; this in the present case is sufficient to evaporate gradually the vinegar. Accordingly, oxygen, aqueous vapour, fumes of vinegar, and carbonic acid, are present in the air of the white-lead chambers. If you suppose that these substances combine with the lead in the succession just mentioned, the following order of changes will take place;—1. oxide of lead; 2. hydrated oxide of lead; 3. acetate of oxide of lead; 4. basic carbonate of oxide of lead. Thus there is formed first oxide of lead, which, just as in the former process, is converted into carbonate of oxide of lead, through the mediation of acetic acid. The finest kind of white lead is that of Krems, called on the continent of Europe *white of Kremnitz.*

c. By the *French method*, the white lead is prepared in the moist way by conducting carbonic acid into a solution of basic acetate of lead (Goulard's extract). As was seen above (§ 337), a solution of sugar of lead can dissolve still another atom of oxide of lead; this is precipitated by the carbonic acid as white lead, whereby neutral acetate of lead is once more formed in the liquid, which is again digested with litharge, and afterwards treated with carbonic acid. In this way one pound of sugar of lead may be made gradually to dissolve, and again precipitate as white lead many pounds of litharge. The white lead obtained by this method has indeed a dazzling white colour, but it does not possess so much body as that prepared in the English or Dutch manner. The cheaper sorts are obtained by mixing white lead with powdered sulphate of baryta; the latter remains behind when white lead is dissolved in diluted nitric acid. On heating white lead, the carbonic acid and water are expelled, and the yellow residue is oxide of lead.

340. *Lead-Tree.—Experiment.*—Dissolve half an ounce of sugar of lead in six ounces of water, clarify the liquid by adding some drops of acetic acid, pour it into a phial, and then suspend in the latter a zinc rod, by attaching it to the cork; the zinc is soon covered with a grey coating, from which brilliant metallic spangles will gradually shoot forth, finally filling up the interior of the phial. They consist of pure lead (*the lead-tree*). After twenty-four hours, no trace of lead can be found in the solution; it has been replaced by the acetate of zinc; the stronger zinc has abstracted from the weaker lead all its oxygen and acetic acid. By this experiment, not only the difference in the strength of affinity of these two metals is clearly shown, but it beautifully illustrates also the stoichiometrical law of chemical combination and decomposition; for it is only necessary to weigh the lead formed, and the piece of zinc before and after the experiment, to ascertain that the weight of the precipitated lead is to the loss of zinc as 1294 to 407. An atom of lead has thus been replaced by an atom of zinc.

Fig. 153.



Lead and Sulphur.

341. *Sulphuret of Lead* ($Pb\,S$).—*Experiment.*—Add some sulphuretted hydrogen to a solution of sugar of lead; the deep black precipitate is sulphuret of lead. (§ 133.) One grain of sugar of lead dissolved in two pounds of water shows itself in this manner by a brown colour; so that we have in sulphuretted hydrogen an exceedingly delicate test for salts of lead.

In this combination, namely, as sulphuret of lead, we most frequently find lead in nature, and from it alone metallic lead is obtained on a large scale. This ore is called *galena*, and is easily recognised by its greyish-black colour, its shining metallic lustre, its cubic form, and its great specific gravity.

342. *Preparation of Lead.*—Sulphur is so firmly combined with the metals in the sulphurets, that it is impossible to expel it as easily as oxygen, for instance, by heating it with charcoal. Therefore a circuitous method must be adopted—namely, first to convert the metallic sulphuret into an oxide (*roasting*), and then to expel the oxygen (*reduction*). To effect this the galena is heated continuously with access of air, whereby both the lead and the sulphur are combined with oxygen. The lead is converted into oxide of lead, which remains behind, and the sulphur into sulphurous acid, which escapes; some sulphate of lead is also formed at the same time. The roasted galena consists, therefore, essentially of oxide of lead (together with some sulphate of lead); this has now only to be heated with charcoal in a reverberatory or blast-furnace, in order to separate the metallic lead (*lead-works*).

A second mode of freeing the lead from sulphur consists in heating the galena with a metal which has a greater affinity for sulphur, and replaces the lead. Such a metal is iron. Iron and sulphuret of lead are mutually converted into lead and sulphuret of iron. The iron acts here just in the same way that the zinc did in the formation of the lead-tree. One atom of iron replaces one atom of lead; therefore 28 pounds of iron can separate or throw down 104 pounds of metallic lead.

343. *Lead Shot.*—Lead may be granulated by pouring it through a broom into water, as described under zinc. The same principle is applied in the manufacture of *shot*, only that an iron cullender is used instead of a broom, and the drops of lead are let fall from such a height that they solidify before reaching the water. For making the largest-sized shot, a tower of at least 150 feet high is required. A small quantity of arsenic is usually added to the lead, to render the drops perfectly globular. As lead and arsenic are both inimical to health, shot should never be used for washing out bottles.

BISMUTH, BISMUTHUM (Bi).

At. Wt. = 213.—Sp. Gr. = 9.8.

344. *Bismuth* is a metal chiefly found in Saxony. It frequently accompanies the cobalt ores, and, as already mentioned, in the smelting of this ore for smalt, it separates as cobalt-speiss, nickel also being generally present. The metal is pro-

cured from this, and also from the native ore, by a very simple process. It occurs both in the ores and in the speiss in a pure state, when it melts at a temperature which need be only two and a half times higher than that of boiling water; consequently, it is only necessary to heat the ores moderately upon an inclined plate, when the bismuth melts and flows off below, while the other metals or ores, together with the gangue, remain behind unmelted. This method of working the metal is called *eliquation*. Bismuth is brittle, has a crystalline laminated texture, and a reddish-white colour.

Experiments with Bismuth.

345. *Experiment.*—Heat a piece of bismuth upon charcoal before the blow-pipe; it melts with the ejection of sparks, and volatilises at a higher temperature with brisk ebullition. A portion of the fumes condense on the charcoal, coating it with a yellow powder; this is oxide of bismuth ($Bi_2 O_3$). If you throw the glowing metallic bead into a small paper box, it divides into small globules, which, while still glowing, will skip about for some moments. An odour like that of garlic, which is frequently emitted during the ignition, proceeds from arsenic, small quantities of which occur in almost all commercial bismuth.

346. *Experiment.*—Melt together in a ladle two drachms of bismuth, one drachm of lead, and one drachm of tin. The alloy formed has the very remarkable property of becoming completely liquid when thrown into boiling water. Bismuth melts at 482° F. (250° C.), lead at 608° F. (320° C.), tin at 446° F. (230° C.); and yet the mixture of these three metals melts below 212° F. (100° C.) By increasing the quantity of lead, alloys may be prepared *which readily become liquid* at any temperature desired above 212° F. (100° C.) They are sometimes employed as safety-plates in steam-boilers. The heat of the steam increases with the tension of the steam in the boiler; therefore the alloy to be used has only to be so selected that, in case of a too great increase of steam, the plate may be melted by the heat of the steam before an explosion of the boiler itself can take place. As these alloys, in their melted state, do not burn the wood, they are also very well adapted for making metallic copies of engraved wooden moulds for calico-printing

and block impressions. This alloy is called *Rose's metal*, after the inventor.

347. *Experiment.*—Bismuth is most easily dissolved by *nitric acid.* Dissolve some bismuth at a moderate heat in this acid, and pour the solution into a large quantity of water; it becomes very turbid, and, after standing quietly, a white precipitate subsides, which contains only one-fourth as much nitric acid as the salt which crystallises out from the bismuth solution when you let it cool. This powder is *subnitrate of oxide of bismuth*, and is used as a medicine. A small proportion of oxide of bismuth, with a large proportion of nitric acid, remains dissolved in the liquid. The annexed diagram denotes the decomposition hereby taking place, which is of more general interest, as showing that the affinities of bodies for each other may be changed by greater or less dilution with water.

Acid salt.	Soluble.
Bi_2O_3	$3NO_5$
Bi_2O_3	$3NO_5$
Bi_2O_3	$3NO_5$
Bi_2O_3	$3NO_5$
Basic salt.	Insoluble.

The salts of bismuth may be recognised by this behaviour with water. By adding sulphuretted hydrogen to the solution remaining from the former experiment, you obtain a brownish black precipitate of *sulphuret of bismuth*.

COPPER, CUPRUM (Cu).

At. Wt. = 32.—Sp. Gr. = 8.8.

348. In ancient times copper was chiefly obtained from the island of Cyprus, where its ores were found in great abundance; this explains the name, *cuprum*. It being afterwards deemed expedient to give mythological names to the metals, copper received the name of *Venus*, the protecting goddess of Cyprus, and the sign ♀. Copper possesses several excellent properties, which have rendered it an exceedingly useful metal.

a.) It is *ductile*, and at the same time very *strong* and *tenacious*, so that it may be hammered out into plates, which, even when very thin, still hold firmly together.

b.) It *fuses with difficulty* (its point of fusion being 2192° F. (1200° C.); therefore it is excellently adapted for such articles as are to be exposed to a great heat—for instance, kettles, pans, boilers, moulds for casting, &c.

c.) When exposed to the air, it *suffers from rust much less* than iron; for this reason, copper utensils are much more durable than iron ones. Sheet-copper is employed for sheathing ships, and for roofing towers and other buildings.

d.) It is tolerably hard, and therefore wears out but slowly on use, as in copper plates for engravings, and rollers of print-works.

e.) With zinc, tin, and nickel, it forms very useful *alloys*, such as brass, tombac, bronze, bell-metal, cannon-metal, German silver, &c.

f.) It is precipitated from its solutions by the galvanic current as a firm coherent mass; on this principle, impressions of other bodies are produced by the modern process of *electro-metallurgy*.

g.) It yields with oxygen and several acids insoluble combinations of a beautiful green and blue colour, of various application in painting.

Although copper possesses no smell, yet it imparts to moist hands, and to the water which has long been standing in vessels made of it (as boilers or kettles), a peculiarly disagreeable odour.

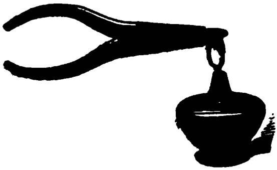
Experiments with Copper.

349. In the moist air, copper slowly turns grey and afterwards green (native mineral-green). Copper, like zinc, attracts, not merely oxygen and water, but also carbonic acid from the air; the green coating is the *hydrated basic carbonate of copper*. In Siberia this combination occurs in large beds in the earth, and is then called *malachite*. The celebrated Russian copper is principally obtained from it; and its beautifully mottled varieties are, like marble, formed into works of art, and are used for ornamenting palaces, &c. This green body, on receiving still more carbonic acid, acquires a beautiful blue colour, and is converted into *sesquibasic carbonate of copper*, which likewise occurs native as a copper ore, under the name of *blue carbonate of copper*. The artificially prepared is called *mountain blue*, and is employed as a pigment, particularly for painting walls, its colour not being changed, like Prussian blue, by the lime of the walls.

350. *Experiment.*—Hold a brightly polished copper coin over the flame of a spirit-lamp; the colour changes from yellow

to crimson, violet, and blue, and finally passes over to a dark grey. These iridescent hues present a particularly beautiful appearance by holding the coin obliquely in the middle of the flame, and moving it to and fro; in the centre of the flame the coating vanishes, but it instantaneously reappears, as soon as the coin reaches or extends beyond the external border of the flame. On speedily quenching the coin in water, it becomes brownish-red; this red coating is *suboxide of copper* (Cu_2O). Such a coating is often intentionally produced upon copper medals, as it is less liable to change in the air than the brilliant metallic copper (*bronzing of copper, bronze medals*). Suboxide of copper, when thrown into melting glass, colours it *blood-red;* in this manner a beautiful red colour is flashed on glass in the glass factories. This accounts, also, for the red colour of the slag which forms during the calcination and fusion of copper.

Fig. 154.



351. *Protoxide of Copper* (CuO).—If the copper coin is left for some time in the point of the flame, it acquires a black appearance; *protoxide of copper* is formed, which has a black colour, and contains as much again oxygen as the red suboxide. If suddenly quenched, the oxide flies off, and the red appearance of the coin shews that the suboxide is also present beneath the film of the protoxide. By long-continued ignition the whole mass of the coin may be converted into suboxide, and by still longer heating, completely, at last, into protoxide. The glowing cinders, which fall off in the workshops of the coppersmith (copper scales), consist of a mixture of the suboxide with the protoxide.

Experiment.—Triturate a small quantity of borax with a scale of the black oxide of copper, and melt it into a bead on a platinum wire before the blow-pipe; the oxide of copper will dissolve in the borax, and form a *green* glass. Oxide of copper is made use of in glass and porcelain painting. If introduced into the inner flame, the green colour passes over to red, because the oxide is there reduced to suboxide of copper.

The oxides of copper may also easily be prepared in the humid way, but they have then a very different colour.

352. *Hydrated Oxide of Copper* (CuO, HO.)—*Experi-*

ment.—Add to a solution of the previously mentioned *blue vitriol*, or sulphate of copper, a solution of caustic potassa; a greenish-blue powder is precipitated; it is *hydrated oxide of copper*. The black oxide yields, also, chemically combined with water, a blue body. Mixed with gypsum this forms a light powder, the well-known *Bremen blue*. Boil a portion of the liquid; the precipitate will become black, because at the boiling point the combination between the oxide of copper and the water is destroyed;—another example of chemical decomposition occasioned by mere elevation of temperature.

353. *Ammoniated Oxide of Copper*.—*Experiment*.—Repeat the former experiment, but instead of potassa take ammonia; here also the hydrated oxide of copper is first precipitated, but this is redissolved by adding more ammonia, forming a splendid *blue liquid*. Ammonia is therefore a test for salts of copper. Pour upon the blue liquid an equal quantity of strong alcohol, and direct the stream against the side of the glass, so that the alcohol may float on the surface; after the lapse of twenty-four hours, a mass of dark-blue acicular crystals is perceptible, which consist of a combination of sulphate of copper with ammonia, and are called *ammonio-sulphate of copper*. By dissolving them in water, the *blue liquid* of the apothecaries' show-bottles is prepared. The alcohol effects that which is otherwise attained by boiling, namely, a removal of the water; it withdraws from the blue liquid a portion of its water, and the double salt, which is insoluble in alcohol, is separated. The water may be abstracted, also, in this way from other solutions of salts, which would undergo a decomposition on the evaporation of the water by heat.

354. *Experiment*.—Add to a diluted solution of blue vitriol a small quantity of pulverised sugar of milk, and then rather more liquid potassa than is necessary to precipitate the hydrated oxide of copper, and heat the mixture; the blue colour will soon pass into a yellowish-red. The yellowish-red precipitate is *suboxide of copper*, which is formed from the protoxide of copper, because the sugar is able to abstract from the latter half its oxygen. The same compound, but of a more beautiful red colour, is obtained by boiling verdigris with vinegar, and then adding some honey to the solution obtained, and again boiling. Thus is easily explained why a red deposit always subsides from the oxymel of subacetate of copper in the apothe-

caries' shops; in the slow separation which occurs in the latter case, small distinct crystals are frequently formed.

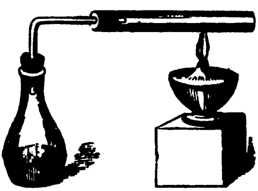
Reduction of the Copper Compounds to Metals.

355. *Experiment.*—Rub together some grains of blue vitriol, carbonate of soda, and *charcoal;* ignite the mixture strongly for some minutes before the blow-pipe, and then elutriate the black mass with water; numberless small spangles of metallic copper will remain behind on the bottom of the vessel. The carbonate of soda takes the sulphuric acid from the blue vitriol, and the charcoal the oxygen from the oxide of copper.

356. *Experiment.*—If half an ounce of blue vitriol is heated to boiling with an ounce and a half of water in a porcelain bowl, and then boiled a few minutes with some granulated *zinc,* the metallic copper separates as a powder, since the zinc has a greater affinity than copper for oxygen and for sulphuric acid. The powder obtained is washed, and then boiled with water and a few drops of sulphuric acid, in order to remove all the zinc. It must be dried quickly, but not at a high heat, for copper in this state of minute subdivision attracts oxygen with more avidity than when it is in a compact mass.

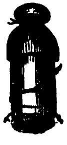
357. *Experiment.*—Introduce some hydrated oxide of copper into a test-tube, the bottom of which is broken, heat it, and then pass over it a stream of *hydrogen,* which is evolved by zinc and diluted sulphuric acid; in the heat, the hydrogen abstracts from the oxide of copper its oxygen, and forms with it water, which escapes in company with the hydrated water. This method is frequently employed for the reduction of ores on a small scale.

Fig. 155.



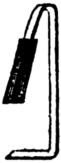
358. *Experiment.*—Push an iron rod into a good-sized, large-mouthed phial, forcibly enough to break out the bottom, file off the sharp edges of the fractured part, and bind some moistened bladder over the mouth of the phial. Then twist a wire firmly round the phial, in such a manner as to form two or three supports, by means of which it may be suspended in a tumbler.

Fig. 156.



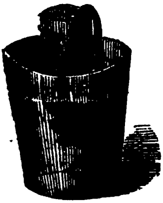
Let a strip of strong sheet zinc, of the width of

Fig. 157.



the finger, and five inches long, be soldered to a strip of thin copper plate, ten inches long, and bend the strip of copper as represented in the annexed figure. Put a coin upon the lower horizontal part of the copper strip,—for instance, a bright half-crown,—or some other metallic object, the impression of which you wish to take. Now fill the phial three-quarters full with very diluted sulphuric acid (one drachm of sulphuric acid to two ounces of water), introduce the zinc, and suspend the apparatus in a tumbler, in which a saturated solution of blue vitriol, and also a few whole crystals of blue vitriol, have been put. In the course of a few minutes the coin will be covered with a thin film of metallic copper, and after several days with a layer several lines in thickness, which may be removed as a coherent mass. Tallow or wax must be smeared over those parts of the coin and plate on which the copper is not to be deposited. The sunk impression thus obtained may be used in the same way again, instead of the coin, as a mould for obtaining a raised impression. When the evolution of the gas in the phial has ceased, a few drops of strong sulphuric acid may be stirred in, or the liquid, which contains sulphate of zinc in solution, may be replaced by a fresh supply of diluted sulphuric acid. Salt water may also be used instead of sulphuric acid, but then the separation of the copper takes place more slowly.

Fig. 158.



The decomposition of the blue vitriol has, in this case, been effected by the *galvanic current*, which is always generated when different kinds of metals come in contact, or are introduced into different liquids. The bladder is a porous substance, through which the galvanic current may pass. Galvanism here takes the place of the plastic artist, and hence the term *galvano-plastic*, applied in Germany to electro-metallurgy. A solution of gold or silver may be decomposed in the same manner (galvanic gilding and silvering).

Copper and Acids.

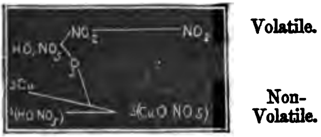
359. *Chloride of Copper* (Cu Cl).—*Experiment.*—If muriatic acid is added to oxide of copper, a green solution is ob-

tained, and from it, by evaporation, a green salt, *chloride of copper*, or muriate of oxide of copper. Introduce some of it into the wick of a spirit-lamp; it dissolves in the alcohol, and colours the flame green. Write on paper with a very diluted solution of it: the colour of the writing changes on heating, and again on cooling, as in the case of chloride of cobalt. (§ 308.) Metallic copper dissolves but very slowly, and with access of oxygen, in muriatic acid.

For *Sulphate of Oxide of Copper, or Blue Vitriol,* see § 175.

360. *Nitrate of Oxide of Copper* ($Cu\,O, N\,O_5 + 5\,H\,O$).

Copper dissolves very readily in nitric acid, forming a blue liquid (§ 162); if the solution is set aside in a warm place, blue crystals of *nitrate of copper* are deposited, which deliquesce in the air. The accompanying diagram serves to illustrate the process attending the solution of copper, as well as of most other metals, in nitric acid. It is already known that the nitric oxide gas which escapes becomes nitrous acid on coming into contact with the air.



Experiment.—Envelop quickly in *tinfoil* some crystals of nitrate of copper, moistened with a drop of water, and press the parcel compactly together, and put it upon a stone; flames and smoke will soon break forth from the bubbling mass, because the tin overpowers the nitric acid, and by means of its oxygen becomes oxidised into oxide of tin.

Oxide of copper forms, with phosphoric, arsenic, oxalic, and silicic acids, insoluble blue or green compounds, in the same way as with carbonic acid.

361. *Verdigris.—Experiment.*—By sprinkling a copper coin from time to time with vinegar, it becomes gradually covered with a green coating. When copper is rusted merely by exposure to the moisture of the atmosphere, or of the earth, *basic carbonate of copper* is formed; but when the rusting is effected by vinegar, *basic acetate of copper* is formed. The latter is the verdigris of commerce. It is prepared on a large scale, either directly from copper and vinegar (green or German verdigris), or indirectly by packing sheets of copper with the

refuse of pressed grapes, since the juice still adhering to the mash gradually passes over into vinegar (blue or French verdigris). Verdigris boiled with vinegar gives a blue solution, from which, on cooling, dark green crystals of neutral acetate of oxide of copper $(\mathrm{Cu\,O\,\overline{A} + H\,O})$ are deposited (crystallised or distilled verdigris).

Verdigris, like all the salts of copper, is *very poisonous*; the white of eggs and milk are efficacious antidotes. Polished iron, ammonia, sulphuretted hydrogen, and especially ferrocyanide of potassium (§ 292), serve for the detection of salts of copper.

Copper and Sulphur.

362. *Experiment.*—If some sulphuretted hydrogen water is added to a solution of any of the copper salts, a black precipitate of *sulphuret of copper* is produced. (§ 131.) Heat this, after it has settled and the liquid has been decanted, with some drops of nitric or muriatic acid; the sulphuret of copper is decomposed and dissolved, while nitrate or muriate of copper is formed. This mode is universally employed on a small scale, especially in analysis, in order to convert metallic sulphurets into soluble salts.

363. *Preparation of Copper.*—The *sulphuret of copper* is the most common ore from which copper is extracted. It is seldom found pure, but mostly combined with sulphuret of iron, as in *copper pyrites*. The process of the reduction and smelting of copper is, accordingly, very tedious, as not only the sulphur, but also the iron, must be got rid of. This is effected —1st, by roasting in the air, whereby the copper is converted into oxide of copper, the iron into black oxide of iron, and the sulphur into sulphurous acid; 2nd, by melting the roasted ore with charcoal and some silicious substance, by which means metallic copper and carbonic oxide are formed from the oxide of copper and the charcoal, and silicate of protoxide of iron (iron slag) from the protoxide of iron and quartz. What appears thus simple is, in reality, so difficult an operation, that the roasting and melting must often be alternately repeated ten or twenty times in order to remove all the iron and sulphur. The melted mass, which is obtained when about half the iron and sulphur is abstracted, is called *matte* (crude copper); and *black copper*, when it contains only about five per cent. of

these two substances. The complete refining of black copper is effected by melting the metal again, exposing it at the same time to the action of the air, whereby the iron, sulphur, and other foreign metals which may be present, as lead and antimony, are oxidised before the copper. When the black copper contains silver, it is subjected to the process of liquation.

The operation of working the copper is much easier when the ores are combined with oxygen instead of sulphur, as they yield the metallic copper by merely heating with charcoal; but such ores are of too rare occurrence in nature to yield sufficient copper to meet the demand.

364. *Alloys of Copper.*—Copper forms very important alloys with several other metals.

Gold and *copper* form the common gold, *silver* and *copper* the common silver, from which gold and silver articles and coins are made.

The well-known *brass*, and other metallic compounds having the appearance of gold, such as tombac, similor, prince's metal, red brass, &c., are composed of zinc and copper. Spurious *gold-leaf* is made by hammering out tombac into exceedingly thin leaves, which, when finely pulverised, constitutes the so-called *gold bronze*. *Purple* or *copper bronze* is prepared by gently heating the gold-coloured bronze till it turns to a purple-red colour.

Zinc, *nickel*, and *copper* constitute the ingredients of German silver (*packfong*, *white copper*).

Tin and *copper* form a very hard grey alloy, from which statues, cannons, bells, mirrors, &c., are cast (*bronze*, *gun-metal*, *bell-metal*, *speculum-metal*).

MERCURY, HYDRARGYRUM (Hg).

At. Wt. = 200.—Sp. Gr. = 13.5.

365. We have in *mercury* the only metal which is *fluid* at ordinary temperatures; for this reason, and also on account of its silver-white brilliancy, it has been called *hydrargyrum* (water-silver or liquid-silver). But subsequently, from its mobility, it was dedicated to *Mercury*, the most active of the ancient gods, and received his name, the symbol ☿ being at the same time assigned to it. Even now, quicksilver and its various medicinal preparations, such as calomel and corrosive

sublimate, are called mercurial remedies. In the northern parts of Siberia mercury becomes solid every winter, whenever the cold reaches —40° F. (—40° C.); but in our climate it can only be solidified by artificial frigorific mixtures. Its action in the heat also corresponds with this; namely, it boils at 680° F. (360° C.) (consequently with only three and a half times greater difficulty than water), and it is therefore easily volatilised and distilled.

Experiment.—Fasten to the cork of a phial containing mercury a piece of wood, affixing to the bottom of the latter some genuine gold-leaf; the gold, after some days, will have assumed a white colour, and be converted into an alloy of gold and mercury. It is obvious from this, that fumes of mercury must be contained in the air of the phial, and that mercury, like water, *evaporates slowly even at ordinary temperatures.* The vapour of mercury, and the preparations of mercury, are very injurious; they first produce involuntary salivation, and afterwards lingering, dangerous maladies; therefore, in experimenting with mercury, not only the inhalation of the fumes should be avoided, but it must be weighed and decanted over a bowl, so that, if any portion of it should happen to be spilt, it may not fall upon the floor. Spirit-thermometers only should be suspended in sleeping-apartments and sitting-rooms, since, from the accidental breaking of the mercurial thermometer, the atmosphere would be vitiated by the mercury running into the chinks of the boards, from which it could be removed only with great difficulty. The same rule applies, too, to green-houses, as the fumes of mercury are also poisonous to plants. As, in comparison with water, mercury boils at a very high, and freezes at a very low temperature, and as it has a great specific weight, it is for these reasons excellently adapted to the construction of thermometers, barometers, areometers, &c. (§§ 16, 24, 93.) Its chief use in areometers is to lower the centre of gravity, thereby forcing the instrument to float in an upright position. In the less accurate areometers, lead shot are frequently substituted for mercury.

Mercury and Acids.

366. Mercury, if quite pure, retains its metallic lustre in the air and water, and it is therefore ranked among the *noble* metals; but if it is mixed or adulterated with other metals, as lead,

tin, or bismuth, a grey film will gradually form upon its surface. On account of the slight affinity of the noble metals for oxygen, their oxides cannot be prepared directly by exposing them to the air, or by heating them to redness, but only indirectly, the best way being to treat the metals with acids. The most powerful solvent for mercury is *nitric acid;* the cheapest is sulphuric acid.

367. *Nitrate of the Protoxide of Mercury* ($Hg\,O,\,N\,O_5$).—*Experiment.*—Pour into a porcelain dish one ounce of mercury, one drachm of water, and half an ounce of nitric acid; cover the vessel and place it aside for several days; you will then find the mercury covered with white crystals; they are the nitrate of the *protoxide of mercury.* In the *cold,* two atoms of mercury take up only one atom of oxygen from the nitric acid. Put a part of the crystals into a phial, and pour over them some water; a milky turbidness is produced, as in the solution of bismuth (§ 347), but it disappears again on the addition of a few drops of nitric acid.

This solution of protoxide of mercury serves for the following experiments:

368. *Protoxide of Mercury* ($Hg\,O$).—*Experiment.*—To a part of the solution of protoxide of mercury is added a solution of potassa; a *black* precipitate of *protoxide of mercury* is formed. This preparation must be kept in an opaque phial, because it is resolved by the light into peroxide of mercury and metallic mercury. If ammonia is used instead of the potassa, a triple combination is obtained of protoxide of mercury, ammonia, and nitric acid.

369. *Experiment.*—If a drop of the solution of mercury is rubbed upon a copper coin, the mercury separates as metal, and effects a *false silvering* of the copper.

Experiment.—Make a stroke across a brass plate with a wooden stick that has been dipped in the solution of mercury; if the plate is afterwards bent at this place it will break, as though it had been cut; because the reduced mercury penetrates the brass with great quickness, and renders it brittle. Thus the brazier can make use of this solution instead of shears.

370. *Protochloride of Mercury* ($Hg\,Cl$).—*Experiment.*—Add some muriatic acid, or a solution of common salt, to a part of the diluted solution of the protoxide of mercury; a heavy

white precipitate of *muriate of the protoxide of mercury*, or *protochloride of mercury*, is produced, which is *insoluble* in water. When well washed and dried, this salt of mercury forms the highly important medicine known as *calomel (precipitated)*. If some of it is moistened with potassa or lime water, it becomes black, owing to the protoxide of mercury being set free; thus is explained the Greek name *calomel* (καλός, beautiful, μέλας, black). This combination is also slowly decomposed by light. Formerly, protochloride of mercury was universally prepared from the perchloride of mercury and metallic mercury, which were rubbed together and sublimed (*sublimed calomel*). By this process $Hg\ Cl_2$ and Hg are converted into $Hg\ Cl$, a heavy, crystalline, white mass, which is pulverised and washed many times with boiling water. The powder thus obtained has a slight yellowish tinge.

371. *Nitrate of the Peroxide of Mercury* ($Hg\ O_2,\ N\ O_5$).—*Experiment.*—Dissolve in a flask, at a moderate heat, some mercury in nitric acid, and when completely dissolved, boil the liquid briskly for some minutes. While boiling, the mercury combines with as much again oxygen as in the cold, and accordingly *nitrate of peroxide of mercury* is produced, which crystallises from the liquid on cooling. A solution of this salt gives, with potassa or lime-water, a *yellowish-red* precipitate of peroxide of mercury, but it is *not* rendered turbid by muriatic acid or common salt.

372. *Peroxide of Mercury* ($Hg\ O_2$).—*Experiment.*—Heat gradually in a test-tube some of the crystals of the nitrate of peroxide of mercury, till they cease to give off fumes; the nitric acid escapes, partly decomposed into nitrous acid, the peroxide of mercury remains behind. Its red colour, however, appears first on cooling; as long as it is hot, it looks black. It is resolved by too strong a heat into oxygen and metallic mercury. (§ 56.)

373. *Perchloride of Mercury* ($Hg\ Cl_2$).—*Experiment.*—Heat some peroxide of mercury with muriatic acid, and continue adding the latter till a complete solution is obtained; the white prismatic crystals which separate on cooling are muriate of peroxide of mercury, *bi-* or *perchloride of mercury*,—one of the *most violent poisons.* The same compound is obtained on a large scale, in white, transparent, heavy masses, by the sublimation of the sulphate of the peroxide of mercury with common

salt; hence its common name, *corrosive sublimate.* Potassa turns calomel black, but corrosive sublimate yellowish-red. Poisonous substances commonly have the property of protecting vegetable and animal substances from decay, and perchloride of mercury possesses this power in a high degree. For this reason, wood for ship-building, and sleepers for railroads, are saturated with a solution of it in water (*Kyanizing*); the plants of herbariums are passed through a solution of it in alcohol, &c. It must not be forgotten, that these things themselves are thereby rendered poisonous. In cases of poisoning, large quantities of whites of eggs must immediately be administered, as the albumen forms with the bichloride of mercury an insoluble compound.

374. If ammonia is added to a solution of perchloride of mercury, then red oxide is not precipitated, but a white body, which is likewise (as in § 368) a triple compound, consisting of mercury, chlorine, and ammonia. It is kept in the apothecaries' shops as an external remedial application, under the name of *white precipitate,*

375. *Experiment.*—Add some salt of tin (protochloride of tin) to another portion of the solution, and heat the liquid; a grey powder will separate; this is *mercury in a state of extreme comminution.* If you boil it with muriatic acid, after having decanted the liquid, the powder finally forms into globules. The protochloride of tin has, so strong a tendency to pass over into perchloride, that it abstracts the chlorine from the perchloride of mercury. This action is made available in analysis for detecting the salts of mercury.

Mercury may be minutely divided also by long trituration with viscous substances, as fat, tallow, wax, &c., so that no particles of it can be discerned by the naked eye. In this manner, mercurial ointment and mercurial plasters are prepared by the apothecaries.

Mercury and Sulphur.

376. *Persulphuret of Mercury* ($Hg\ S_2$).—*Experiment.*—If a solution of perchloride of mercury is agitated with a little sulphuretted hydrogen water, or sulphuret of ammonium, a white precipitate is formed, which, on adding more of the precipitating body, becomes yellow, brown, and finally black; the black substance is the *persulphuret of mercury.* This com-

pound is also obtained by mixing mercury with melted sulphur, or indeed by rubbing it for a day with flowers of sulphur *(Ethiops mineral)*. If this black sulphuret of mercury is sublimed in a glass tube, then a blackish-red crystalline mass is obtained, the colour of which, by friction, passes into the most magnificent scarlet-red. The persulphuret of quicksilver in this state is called *vermilion*, or cinnabar. The red and the black persulphuret of mercury have precisely one and the same composition, and yet a very great difference in appearance; they afford one of the finest examples of *isomeric combinations*. In both the red and black sulphuret of mercury, two atoms of sulphur are always combined with one atom of mercury, or one ounce of sulphur with 6¼ ounces of mercury. Vermilion is also frequently prepared in factories in the moist way, by triturating together for a day mercury, sulphur, and a solution of potassa. When vermilion is pure, it volatilises completely on a glowing coal, emitting, at the same time, a blue sulphurous flame; but if adulterated with minium, beads of metallic lead remain behind. On account of its insolubility, it is far less prejudicial to health than the other compounds of mercury.

Cinnabar also occurs in nature, and we have in it the most important ore, from which we obtain mercury on a large scale. Small globules of pure mercury are also found in many porous stones.

377. *Preparation on a large Scale.*—*Experiment.*—Mix a little vermilion with half its quantity of iron filings, and heat the mixture in a dry test-tube; small globules of mercury will soon deposit themselves on the upper cooler portions of the glass, while the sulphur remains combined with the iron. Mercury is obtained in a similar manner from native cinnabar, by distilling it with iron or lime in large iron retorts; the foreign earths remain behind in the latter. This heavy liquid is imported either in leather bags, iron flasks, or hollowed out bamboo-canes.

378. *Amalgams.*—*Experiment.*—Introduce a globule of mercury into a porcelain dish, put upon it a piece of lead, and let them remain for some time in contact; both metals will intimately combine together. If the proportion of mercury is small, a friable mass is produced, but by increasing the quantity, a paste, and, if still more is added, a liquid solution, is obtained.

Mercury will combine in a similar manner with most of the metals, forming what are called *amalgams*. The *amalgam of tin* is especially important for silvering glass, so that the rays of light falling upon the surface of the glass may be reflected by the bright coating of the amalgam. Such glasses are called *mirrors*.

SILVER, ARGENTUM (Ag).

At. Wt. = 108.—Sp. Gr. = 10.5.

379. *Silver* conveys to us a distinct conception of what is understood by a *noble* metal. We can let a coin of pure silver remain exposed to the air, we can throw it into the water, or bury it in the earth; it does not rust. We can subject it to the greatest heat; it may perhaps change its form, and melt at about 1832° F. (1000° C.), but it does not oxidise or volatilise. Silver has also a *higher value* than most other metals, not only on account of its *unchangeableness*, but because its ores are of comparatively rare occurrence in nature, and the process of obtaining them is more costly than that of other ores. A pound of silver is worth about three sovereigns. It is principally on account of these two circumstances that silver and gold have been made to serve as the medium of exchange in the sale and purchase of commodities,—that they are used as *money*. The beautiful lustre of silver, and its extraordinary ductility, have moreover rendered it a favourite and appropriate metal for various articles of luxury, and for plating other metals. The old name for silver is *Luna* (☽).

Alloys of Silver.—As pure silver is very soft, and would quickly wear out in using, it is generally alloyed with copper, whereby it is rendered harder, without losing its ductility. If the proportion of copper is only one-fourth, the silver still retains its beautiful white colour; but if more copper is added, the alloy becomes yellow, and finally red, by use. It has been agreed to call a quantity of pure silver, weighing 8 ounces, a *fine mark*. If the sample is an alloy of silver and copper, the question is always asked, What is the proportion of pure silver in 8 ounces? If it amounts to 7½ ounces, the silver is said to be 7½ ounces fine; if 6, or 4, or 2 ounces of silver are contained in it, it is understood to be 6, or 4, or 2 ounces fine. Accordingly, silver 6 ounces fine contains three-fourths of silver and one-fourth of copper. The standard silver, used in England to make shillings, half-crowns, &c., consists of $11\frac{1}{10}$ parts of pure silver and $\frac{9}{10}$ of copper. When recently stamped, they are yellow, but the surface of them is rendered white by boiling them with cream of tartar and water, because some of the copper is thereby dissolved, and consequently a thin coating of pure silver is produced. By *due weight* is understood the weight of a coin; by *value*, the fineness of the silver employed.

Experiments with Silver.

380. In order to oxidise silver, it must be treated with acids; it dissolves most readily in *nitric acid.* In the following experiments care must be taken not to touch the solution of silver with the finger, as the skin is stained *black* by it.

Nitrate of Oxide of Silver.—Experiment.—Add some nitric acid to a silver coin placed in a beaker-glass, which must be put in a warm place; if after a few days the coin is not entirely dissolved, add more nitric acid, and wait till the solution is completed. The blue solution consists of oxide of silver and of oxide of copper, both combined with nitric acid.

To separate these two metals from each other, put some bright copper coins into the solution, and set it aside in a warm place for a few days, occasionally giving it a circular motion. The separated laminæ are pure silver, which are to be digested with ammonia, until this ceases to be coloured blue. The silver, after being washed and dried, is dissolved for the second time in nitric acid, and the liquid, diluted with water, is kept as *solution of silver.*

Lunar Caustic.—By evaporating this solution, *nitrate of oxide of silver* ($Ag\ O,\ N\ O_5$) is obtained, in white tabular crystals. When these are fused and formed into slender sticks, by casting in brass moulds, they constitute *lunar caustic*, known as a corrosive agent, employed for removing proud-flesh, warts, &c. (fused nitrate of silver). It not only attacks the texture of the skin, and dyes it black, but also other organic substances; on account of this property, is is often employed for dyeing black the hair, and also bones and ivory, as in chessmen, &c. The black colour proceeds from the separation of the oxide of silver. Nitrate of silver forms also the indelible ink used for writing on linen.

381. *Experiments with Nitrate of Silver.*

Experiment a.—Place a small piece of lunar caustic upon charcoal, and heat it before the blow-pipe; it deflagrates and yields *metallic* silver, which may be easily fused at a stronger heat.

Experiment b.—Add some ammonia to a solution of lunar caustic; the dark-grey precipitate is *oxide of silver* ($Ag\ O$). If more ammonia is added, it is redissolved. It would be dangerous to continue this experiment any further, as the oxide of silver combines with ammonia and forms *fulminating silver*, which explodes violently on percussion or friction. Another explosive compound may be prepared by uniting the oxide of silver with fulminic acid.

Experiment c.—*Chloride of Silver.*—Dilute with water part of the solution of silver obtained in § 380, and add to it muriatic acid, or a solution of common salt; you obtain a white curdy precipitate of *chloride of silver* ($Ag\ Cl$). This precipitate is so insoluble in water that it will impart a cloudiness to a solution of silver diluted a millionfold (§ 187); it is, however, easily dissolved by ammonia (test of salts of silver). This relation of the solution of silver to common salt is made use of by silversmiths for testing silver alloyed with copper, as the quantity of pure silver in the alloy may be estimated from the amount of the solution of salt required for its complete precipitation (humid assay of silver). Chloride of silver is also called *horn-silver*, having formerly received this name from the horn-like appearance it assumes on melting.

Experiment d.—After having decanted the supernatant liquid, rub the *chloride of silver* with a cork upon a sheet of paper, and let it dry in a dark place—in a drawer, for instance; it remains white. Now place the sheet partly in a book, so that one-half may be exposed to the light; this part soon acquires a violet, and finally a black colour, while that protected from the light remains white. Thus *light alone* is capable of destroying the affinity between silver and chlorine; the chlorine escapes, but the silver remains, and in this state of fine subdivision its colour is *black*. On this action of the solar light on certain substances were founded the experiments made some years since by the natural philosopher Daguerre, who at length succeeded in making use of the sun as delineator, and of the salts of silver (especially the compounds of silver with chlorine, bromine, and iodine) as crayons or India ink, in producing the so-called *Daguerreotype* or *photographic* impressions.

Experiment e. — *Sulphuret of Silver.*—If you add sulphuretted hydrogen to a solution of silver you obtain a black precipitate of *sulphuret of silver* (Ag S). This compound occurs in nature as the most important silver ore; it is called *silver-glance.* Silver is likewise found in a pure state, or in combination with arsenic and antimony, as *red silver ore.*

382. *Preparation of Silver on a large Scale.*—The preparation of silver from its ores is adapted to the other ores with which the silver ores are commonly mixed. The three following methods are those most frequently resorted to.

a.) *Cupellation.*—Galena generally contains small quantities of silver. In order to extract this, the galena is first reduced, by roasting and smelting with charcoal, to metallic lead, in which the silver is also contained. This mass, containing silver, is then put into a kind of reverberatory furnace, called the *refining hearth,* and which is hollowed out like a kettle; it is there heated for a day, while a constant current of air is passed over the metal, until all the lead is at last converted into oxide. The oxide of lead melts in the heat, and flows off partly as litharge through a tube, and partly soaks into the porous mixture of clay and lime, which has been firmly beaten down on the hearth of the furnace; but the silver, which is not oxidised, remains behind in a metallic state *(refined silver).* This is rendered still purer by being again fused in clay-basins (smaller cupels), which absorb the remainder of the litharge *(fine silver).* If other less noble metals are present in the silver ore, they are likewise oxidised and carried down into the cupel by the litharge. These methods can also be employed on a small scale for estimating the alloys of silver *(assay by the cupel).*

b.) *Liquation Process.*—Many of the copper ores also contain silver, and yield, on reduction, copper containing silver. (§ 363.) The silver is fused and extracted from this ore by means of *lead,* in the same way as potassa is dissolved and extracted from wood-ashes by water. The calcined ore is mixed with a large proportion of lead, and then fused and run into pigs, called *liquation-cakes,* which are placed, with layers of charcoal, upon an inclined hearth. When the coal is ignited, the heat is indeed sufficient to melt the lead, but not the copper; consequently the lead flows off, and carries with it the silver, whilst the copper remains behind. This mixture of lead and silver is finally, as described at *a*, converted into metallic silver and oxide of lead in the refining-hearth.

c.) *Process of Amalgamation.*—Silver is often extracted by means of *mercury* from the ores containing pure silver or sulphuret of silver, but no admixture of lead. But in the case of silver-glance the metallic silver must first be separated from the sulphur. This is done by two operations. In the first, the stamped ore is roasted with common salt, by which process chloride of silver and sulphate of soda are formed; in the second, the roasted ore is mixed with water, iron, and mercury, and kept in constant agitation for some time in closed casks. Chloride of iron and metallic silver are thereby formed, the latter of which is dissolved in the mercury. The excess of mercury is then filtered off, and a solid silver amalgam is obtained by subjecting it to pressure, and the mercury is at last completely removed from the amalgam by distillation.

GOLD, AURUM (Au).

At. Wt. 197.—Sp. Gr. = 19.2.

383. Though *gold* is found in most countries, yet it is disseminated so sparingly, and the separation of it from the rocks or the river-sand in which traces of it occur is attended with so much labour, that it is rendered the most costly of our metals. The value of gold is about fifteen times greater than that of silver.* Its unchangeableness, its beautiful colour, its high lustre, and great density, have stamped it as the noblest metal—the king of metals. It was formerly regarded as the symbol for the king of the stars, and was called Sol, or Sun (☉). It surpasses even silver in ductility, may be beaten out into extremely thin leaves (gold-leaf), and a single grain of gold may be drawn out into a wire five hundred feet in length. As it always exists in a metallic state in nature, and has a very great specific weight, the most simple method of separating it from

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* "Gold is regularly purchased by the Bank of England at the rate of 3*l.* 17*s.* 9*d.*, and issued at the rate of 3*l.* 17*s.* 10½*d.* per ounce of 22 carats (eleven-twelfths) fine."—Waterston's *Cyclopædia of Commerce.*

the sands, or from the stamped ores, is either by washing with water or by amalgamation with mercury.

Pure gold, like pure silver, is somewhat soft, and quickly wears out in using; therefore, when it is to be manufactured into coins or articles of luxury, it is alloyed with other metals, usually *silver* and *copper*, to render it harder. The quantity of pure gold contained in a mass is expressed by the word *carat*, the standard number not being 8, as in silver, but 24. A mark of gold (8 ounces) is divided into 24 parts, or carats. If gold is said to be 18 carats fine, it is understood that the mass consists of three-fourths (18 parts) of gold, and one-fourth (6 parts) of alloy; if 6 carats fine, of one-fourth (6 parts) of gold, and three-fourths (18 parts) of alloy, &c.

384. *Parting of Gold.*—In order to obtain fine gold from alloyed gold, or to separate it from silver containing gold, it is boiled with concentrated *sulphuric acid*, which must be done in iron kettles; the concentrated sulphuric acid does not dissolve the iron. The silver and copper are dissolved with the formation of sulphurous acid, while the gold remains behind undissolved, as a brown powder. From the solution of silver and copper, the silver is precipitated by copper, and blue vitriol is obtained as a secondary product. This operation is called *refining.*

Formerly, with the same view, silver containing gold was dissolved in *nitric acid*, which does not dissolve the gold, though it does silver. In this case the remarkable fact was observed, that the silver was completely dissolved only when three-fourths of silver were present to one fourth of gold (two-thirds of silver, however, is an adequate proportion); hence the term *quartation*. If more than one-fourth or one-third of gold is contained in the alloy, the gold exerts a protecting influence upon the silver, so that the latter is not attacked and dissolved by the nitric acid.

The most simple mode of testing gold is to rub some of it off upon a black flint slate (touchstone), and apply to the mark a drop of aquafortis. If the gold is pure, the yellow stroke remains unchanged, but if alloyed, it partly disappears; if it is only an imitation of gold, for instance, tombac, it entirely dissolves.

385. *Gold and Acids.*—None of the common acids alone can dissolve gold, since this metal is in a high degree indifferent towards oxygen and acids. Chlorine is the only means of

rendering it soluble. (§ 152.) Commonly the chlorine is obtained for this purpose by mixing muriatic with nitric acid; in this mixture, the well-known *aqua regia*, the gold dissolves completely by sufficient heating, and a brownish-yellow liquid is obtained (*solution of gold*). By evaporating this solution to dryness, *terchloride of gold* ($Au\ Cl_3$) is obtained, as a brownish-red deliquescent salt. Metallic gold separates from it on exposure to the light, and likewise separates by introducing phosphorus, iron, zinc, and other metals, into a solution of it.

Experiments with Gold.

386. *Gilding.—Experiment a.*—Dip a dry test-tube into a diluted solution of gold, so as to moisten the bottom of it, and then heat it over the flame of a spirit-lamp; it will become gilded, a proof that gold has only a very feeble affinity for chlorine, since it releases it at a mere gentle heat.

Experiment b.—Drop some of the solution of gold upon blotting-paper; let the paper dry, and then hold it by means of a wire over the flame of a spirit-lamp; you obtain finely-divided gold, mixed with the ashes of the paper as a coherent loose mass. If you rub this for some time upon a bright silver spoon, with a soft cork which has been dipped in salt water, the silver becomes gilt (*cold gilding*). There are other methods of gilding—the *moist gilding*, in which the copper, brass, or silver articles are boiled with a very diluted solution of gold, to which some bicarbonate of soda, or cyanide of potassium has been added; the *hot* or *quicksilver gilding*, by which these articles are smeared with a solution of gold in mercury, and afterwards heated; the *galvanic gilding*, which is done in the same manner as the galvanic coppering. The *silvering* of metals is conducted on the same principle.

387. *Gold Powder.—Experiment.*—Drop into a weak solution of sulphate of iron some muriatic acid, and then some of the solution of gold; the liquid immediately assumes a changeable dark and brownish colour, but it appears of a beautiful blue colour by transmitted light. On standing, a brown substance is deposited, which is gold in the state of minutest subdivision (*gold powder*). The green vitriol is at the same time converted into the sulphate of the sesquioxide of iron, and into sesquichloride of iron; decomposition is thus produced, by the

great tendency of the protoxide of iron to pass over into the sesquioxidé of iron. In this way the workers in gold precipitate that metal from liquids containing it. By triturating gold powder with oil of lavender, the colour made use of by painters for gilding porcelain, glass, &c., is obtained.

388. *Gold and Oxygen.*—If the solution of gold is applied to the skin, or to any other organic substance, it imparts to it on drying a dark purple-coloured stain, proceeding from the *protoxide of gold* (Au O). This protoxide of gold is also formed on the addition of the solution of gold to protochloride of tin (*purple of Cassius*). That the most beautiful purple colour is produced by this on glass and porcelain has already been mentioned, under the head of tin. (§ 322.) Gold may be recognised in its solutions by salt of tin. Teroxide of gold ($Au\ O_3$) is of a brownish-black colour, and comports itself like an acid towards bases. It combines with ammonia, like the oxide of silver, forming fulminating gold.

389. *Sulphuret of Gold.*—When sulphuretted hydrogen is added to a solution of gold, a black precipitate of *sulphuret of gold* is produced, which is soluble in hydrosulphuret of ammonia. Gold cannot be united directly with sulphur, by fusing them together.

PLATINUM (Pt).

At. Wt. = 99.—Sp. Gr. = 21.5.

390. Platinum, a metal of still greater density than gold, was brought in the last century from America, where it was found, in the form of small, flattened grains, mixed with the sand from which the gold was washed. It received the name of *platinum*, derived from the Spanish word *plata*, silver, on account of its resemblance to silver in colour and ductility. It was afterwards found also in the sand of the Ural Mountains, in compact *lumps*, from the size of a lentil to that of a man's fist. Platinum, like gold, is a *noble* metal, and, like iron, is *tenacious*, *ductile*, and *can be welded*, and is, moreover, infusible at the strongest furnace heat. These properties have rendered platinum an invaluable metal to the chemist. Sulphuric and hydrofluoric acids can be distilled in platinum retorts, aquafortis can be boiled in platinum capsules, and substances can be subjected to the strongest white heat in platinum crucibles, or on platinum foil or wire, without the

platinum articles being broken or melted. It is only necessary to be careful that no metal be heated with platinum, as a fusible alloy might thus be formed, and the platinum apparatus be melted or broken even at a moderate heat. The value of platinum is intermediate between that of gold and silver, and in Russia it has been coined into money. It is less adapted for articles of luxury than either of these two metals, its colour not being of a pure, but of a greyish white, and its lustre far inferior to that of silver. It can be fused by the oxyhydrogen blow-pipe, or by the galvanic battery.

391. Platinum, like gold, is dissolved by heating it for a long time with aqua regia; and a dark-brown solution of chloride of platinum = $Pt\ Cl_2$ is obtained (*solution of platinum*). A small quantity of this solution can easily be prepared from one or more pieces of spongy platinum, such as are employed in the Döbereiner hydrogen-lamp.

Experiments with Platinum.

392. *Finely divided Platinum.*—*Experiment.*—Add a few drops of a solution of platinum to a solution of sal ammoniac; the two salts will combine together, forming a yellow insoluble double salt, which is called *chloride of platinum and ammonium.* After settling, decant the supernatant liquid; let the precipitate partly dry in a dish, so that it forms a moist paste; affix it to a platinum wire, several times bent, and hold it in the flame of a spirit-lamp. The sal ammoniac flies off, but the platinum remains behind as a grey, loosely coherent, porous mass, the so-called *spongy platinum.* When held in hydrogen, it becomes red-hot, and inflames the gas. (§ 85.) The porous platinum acts on gases in the same manner as the pump of an air-gun, only far more rapidly and vigorously; it absorbs them, and condenses them so powerfully together into its pores, that the atoms of two different gases often approach each other sufficiently near to combine together chemically. As hydrogen and oxygen are in this instance compelled to unite, so the spongy platinum can force many other gases, which will not directly combine with each other, to enter into combination.

Pure platinum is commonly prepared from spongy platinum, which is heated to whiteness and then quickly compressed by strong pressure. A compact mass is thus obtained, which, on being again heated, may be hammered out into uniform pieces, and afterwards rolled into plates, drawn out into wire, or moulded into crucibles, capsules, &c.

By proper chemical means, platinum may be divided still more minutely than in the case of spongy platinum; it is then obtained in the form of a fine *black powder*, which possesses, in a still higher degree than spongy platinum, the power of condensing gases into its pores; it is called *platinum black*. If some alcohol be dropped upon this platinum black, ignition takes place, with an almost instantaneous conversion of the alcohol into acetic acid. The reason of this change is to be sought for in a combination of the alcohol with the oxygen of the air, which is effected by means of the porous platinum black.

393. *Experiment.*—If you perform the experiment described in § 386 with a solution of platinum, you obtain a coating of metallic platinum upon the glass. The combination between this metal and chlorine is likewise so feeble, that heat alone is able to destroy it.

394. *Experiment.*—Dissolve one of the salts of potassa, and add to it some drops of solution of platinum; here also, as in § 392, a yellow insoluble precipitate is formed, consisting of potassium, platinum, and chlorine. The solution of platinum serves, therefore, as a test for the salts of potassa (and salts of ammonia). The solution of platinum is precipitated black by sulphuretted hydrogen (sulphuret of platinum).

Platinum forms with oxygen a *peroxide* and a *protoxide*; likewise with chlorine, a *perchloride* and a *protochloride*.

Palladium, Iridium, Rhodium, and Osmium.

395. These four metals are, as it were, the satellites of platinum. They are always found in small quantities in the crude platinum sand, and are obtained on the purification of the latter, by a somewhat elaborate process. They also have the character of noble metals.

RETROSPECT OF THE SECOND GROUP OF THE HEAVY METALS.

1. The metals lead, bismuth, copper, mercury, silver, gold, and platinum do not possess the power of decomposing water, that is, of abstracting its oxygen, like the metals of the first

group; therefore, concentrated acids must be employed for their solution.

2. Their lowest degrees of oxidation are bases, while their higher degrees comport themselves sometimes like bases, sometimes like acids.

3. These metals most frequently occur in nature uncombined, or as sulphurets, rarely as oxides.

4. They have a greater specific weight than the metals previously described; it varies from 8.8 to 21.5. (That of iridium is indeed 23.0.)

5. They are all precipitated as *black sulphurets* by sulphuretted hydrogen and hydrosulphuret of ammonia; the sulphurets of gold and platinum are redissolved by the latter reagent.

6. The metals mercury, silver, gold, and platinum, together with the last-named associates of platinum, are called *noble metals*, because they remain bright in the air or in water. When oxidised by other means, by acids, for instance, the oxides may be again resolved merely by heat into metal and oxygen. This is effected with the ignoble metals only by the addition of a reducing agent, as by charcoal.

THIRD GROUP OF HEAVY METALS

TUNGSTEN, MOLYBDENUM, TELLURIUM, TITANIUM, TANTALUM, VANADIUM, NIOBIUM, PELOPIUM.

396. These metals occur only as chemical rarities, and have not yet found any useful application. Their highest degrees of oxidation are clearly defined *acids*. The first two are the most common, as they are sometimes dug out from tin mines,—tungsten as wolfram ore, and molybdenum as sulphuret of molybdenum, or molybdate of lead.

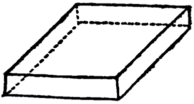
CHROMIUM (Cr).

At. Wt. = 27.—Sp. Gr. = 6.

397. Chromium has only been known within a few decades, and already several of its combinations have become common and valued articles of commerce. The cause of this rapid extension is owing to the beautiful colour of many of the preparations of chromium, on account of which they are excellently adapted for pigments. This also has given rise to the name *chromium* (colour).

The most important ore of chromium, *chromate of iron*, an insignificant looking black mineral, is mostly obtained from North America, and is manufactured in England into a red salt, which consists of *potassa and chromic acid.* The other compounds of chromium are prepared from this salt.

Fig. 159.



398. *The Red Chromate or Bichromate of Potassa* (K O, 2 Cr O_3) is an *acid salt*, for it contains two atoms of chromic acid and one atom of potassa, and commonly occurs in beautiful tabular or prismatic crystals. Rub half an ounce of it with five ounces of water; it will dissolve in it, forming an orange-yellow solution.

Experiment.—Add to one half of this solution a drachm of pure carbonate of potassa, and concentrate by evaporation the liquid, which has become of a pale yellow colour; on cooling, yellow crystals will be deposited. These consist of *neutral chromate of potassa* (K O, Cr O_3). The potassa of the carbonate of potassa has, while the carbonic acid escaped, combined with the second atom of chromic acid. If nitric acid is added to a solution of the yellow salt, the liquid becomes darker, and on evaporation red crystals are obtained, mixed with crystals of nitre. It is obvious that the nitric acid has abstracted half of the potassa.

399. *Chromate of Oxide of Lead* (Pb O, Cr O_3).—*Experiment.*—Add to a portion of the solution of the red salt a solution of sugar of lead, as long as there is any precipitate; this precipitate, when washed and dried, is the well-known *chrome yellow*, and is the richest and most vivid of all the yellow pigments. By mixing it with white substances,—for instance, chalk, talc, clay, gypsum, &c.,—numerous other shades of yellow are obtained, as new-imperial, king's, Paris, &c., yellow; but by mixing it with Prussian blue, the well-known cheap green pigments are obtained, called olive green, Naples green, green cinnabar, &c.

Experiment.—If chrome yellow is stirred up with water and heated with some carbonate of potassa, it passes into *chrome orange*, which is also used as a painter's colour. This contains somewhat *less* chromic acid than the chrome yellow; accordingly, the potassa abstracts from the chrome yellow a portion of the chromic acid, which is rendered apparent by the yellow colour of the liquid filtered off from the chrome orange.

By fusing with nitre, still more, even a half, of the chromic acid may be withdrawn from the chrome yellow; in this way we obtain a beautiful red colour, almost rivalling that of cinnabar, *chrome red*, or basic chromate of oxide of lead (2 Pb O, Cr O_3). Thus we see that the colours of the combinations of lead comport themselves inversely to those of the combinations of potassa; the chrome yellow passes into orange and red by *abstracting* chromic acid, white yellow chromate of potassa, on the contrary, becomes red by *adding* more chromic acid, or, what amounts to the same, by withdrawing potassa.

Experiment.—Chrome yellow has obtained also a very important application in the dyeing and printing of yarns and stuffs. First dip a piece of calico into a solution of chromate of potassa, then, after it has become dry, into a solution of sugar of lead; it is dyed *yellow*. If you now boil a little quicklime with water in a vessel, and then dip the cotton dyed yellow into it for a few moments, it will acquire a *reddish-yellow* colour, because the lime, just like the carbonate of potassa, abstracts some chromic acid from the chrome yellow. It is scarcely necessary to explain any further why chrome yellow cannot be used for painting the walls of apartments. Salts of zinc and baryta are precipitated yellow, salts of the protoxide of mercury brick-red, and salts of silver purple-red, by chromate of potassa.

400. *Sesquioxide of Chromium* ($Cr_2 O_3$).—*Experiment.*—Boil some chrome yellow in a test-tube with muriatic acid; it becomes white, and the liquid green; the white residue consists of muriate of oxide of lead (chloride of lead), but the liquid holds in solution *muriate of the sesquioxide of chromium* (sesquichloride of chromium). A piece of moistened litmus-paper, or of paper smeared with ink, introduced into the tube during the boiling, is bleached, as *chlorine gas* escapes at the same time. The process is analogous to that of the evolution of chlorine from black oxide of manganese, or from aqua regia; the chromic acid gives up half its oxygen, and becomes green *sesquioxide of chromium*, but the oxygen, becoming free, abstracts from a portion of the muriatic acid its hydrogen, and liberates its chlorine. Decant the green solution, dilute it with water, and add to it ammonia; the ammonia combines with the muriatic acid, and the sesquioxide of chromium is precipitated as a *hydrate* having a bluish-

green colour. Dried and ignited, it becomes a dark green *anhydrous oxide.* A fine green is produced by it on porcelain and glass; accordingly it is esteemed as a valuable vitrifiable pigment.

Experiment.—The ease with which chromic acid gives up half of its oxygen may also be shown with chromate of potassa. Dissolve in a test-tube a few grains of red chromate of potassa in warm water; add a few drops of sulphuric acid, and heat the solution still more strongly. If you now add a little sugar or some drops of alcohol to it, a brisk ebullition ensues, and the colour of the solution is changed from red to green; sulphate of potassa and sulphate of sesquioxide of chromium are now contained in the liquid.

401. *Chromic Acid* ($Cr\ O_3$).—*Experiment.*—Reduce to powder half an ounce of red chromate of potassa, put it into a porcelain dish, and then add half an ounce of water and half an ounce of sulphuric acid, and heat the whole, with constant stirring, for five minutes. If a drop of it is put on blotting-paper, it effervesces, and changes its yellowish-red colour to green. When the vessel is entirely cold, add an ounce of cold water to the thick saline mass, stir it a few minutes, and then carefully decant the liquid into a beaker-glass. What remains in the dish is sulphate of potassa; but we have in the liquid a solution of chromic acid, which is precipitated as a red mass by adding to it from one and a half to two ounces of common sulphuric acid. Cover the beaker-glass with a small board, set it aside for twenty-four hours, and then *carefully* pour off the supernatant acid into a glass vessel, and transfer the red paste remaining behind to a new brick, by which the fluid portion is completely absorbed. After twenty-four hours, during which time the precipitate is kept covered with a dish, you obtain the chromic acid, as a crystalline red powder, which must be scraped off from the brick with a glass rod, and put into a wide-mouthed phial, provided with a glass stopper. The following experiments will illustrate the extreme ease with which this highly interesting body decomposes into sesquioxide of chromium and oxygen.

Fig. 160.

Experiment a.—Rinse out a tumbler with strong alcohol, then throw into it a few grains of chromic acid; the alcohol which remains adhering to the tumbler will combine with half the oxygen of the chromic acid, with such energy, that it ignites and instantaneously bursts into flame. The change which the alcohol has hereby undergone is at once revealed by the odour, similar to that of the vinegar chambers; in the latter, the alcohol contained in the spirit, beer, &c., slowly imbibes oxygen from the air, and is converted into vinegar; in the present case this conversion is instantaneously produced by the oxygen of the chromic acid.

Experiment b.—Mix in a small mortar as much chromic acid as can be taken up on the point of a knife with about one quarter as much of powdered camphor (without pressing upon it strongly), and then let some drops of alcohol fall from a considerable height into the mortar; instantaneous ignition and deflagration ensue, almost as if you were burning gunpowder. The residue in the mortar presents, after the decomposition, the appearance of an elegant green mossy vegetation; it consists of sesquioxide of chromium, which at the moment of its formation was scattered by the burning camphor fumes, and was thereby most delicately subdivided.

It is obvious from this action, that chromic acid may be classed under one and the same category with nitric acid, chloric acid, manganic acid, peroxide of manganese, peroxide of lead and chlorine (and the finely divided platinum); it possesses in a high degree the property of forcing other bodies into a combination with oxygen.

ANTIMONY, STIBIUM (Sb).

At. Wt. = 129.—Sp. Gr. = 6.7.

402. *Antimony* has a lamellar crystalline texture, and a white metallic lustre, like bismuth, but without the red tint of the latter; it far exceeds it in brittleness, for it may be easily rubbed to powder in a mortar. The soluble preparations of antimony are undisguised enemies to animal life, and consequently the stomach exerts itself to remove from the body all such compounds introduced into it. This is effected by *vomiting*, and for the very reason of its emetic properties, antimony has become a very important medicine.

403. *Oxide of Antimony* ($Sb\ O_3$).—*Experiment.*—Antimony does not alter in the air, but if a piece of it is heated on charcoal before the blow-pipe, it soon melts, and burns with a white flame, forming an *oxide*, which partly escapes as a white vapour, and is partly deposited as a coating on the charcoal. If you let the melted metallic globule slowly cool, the oxide condenses into crystals, which form around the metal an *espalier* of white points. When thrown into a paper capsule, the white glowing globule will burst into a multitude of small grains, which skip about for some time, leaving in their trail a pulverulent oxide. Antimony generally contains traces of arsenic; hence the smell, like that of garlic, which almost always accompanies its fusion.

404. *Antimonic Acid* ($Sb\ O_5$).—If antimony is treated with nitric acid, it takes up two more atoms of oxygen, and becomes *antimonic acid*, a yellowish powder, insoluble in water and acids. At a glowing heat one atom of oxygen is expelled from this, and a compound of antimonic acid with oxide of antimony remains behind, which may be regarded as *antimonious acid* ($Sb\ O_4$). It is not volatile at a red heat, and has the property of imparting to glass and porcelain a yellow and orange colour.

Experiment.—If some powdered antimony be heated with *nitric acid*, the same thing occurs as with tin; namely, the metal is converted into a white powder, which consists of a mixture of both degrees of oxidation, antimonic acid and oxide of antimony. A similar process takes place by mixing powdered antimony with nitre, and throwing the mixture into a red-hot crucible; in this case only antimonic acid is formed, which remains behind combined with the potassa. The *antimoniate of potassa* may be dissolved by boiling in water, and is then used as a test for the salts of soda, the antimonic acid forming with the soda a very sparingly soluble salt.

405. *Chloride of Antimony.*—Antimony is dissolved only with great difficulty by muriatic acid; a solution is more readily obtained by employing sulphuret of antimony instead of metallic antimony.

Experiment.—Put half an ounce of sulphuret of antimony into a capacious flask; pour over it two ounces and a half of muriatic acid, and heat it in a sand-bath, at first moderately, but afterwards to boiling; the sulphuretted hydrogen, escaping in large quantities, is conducted either into water or into milk of lime, by which it is completely absorbed. The sulphuret of antimony and the muriatic acid are converted into sulphuretted hydrogen and *chloride of antimony* (muriate of oxide of antimony). After several days' repose, decant the clear liquid; it contains chloride of antimony in solution, and was formerly called *butter of antimony.* By continuously rubbing some drops of it upon an iron plate, a very strongly adhering coating of oxide of iron is produced, which imparts to the iron a brown appearance, and renders it less liable to rust. In this way the well-known colour (browning) is given to gun-barrels.

The liquid obtained as a secondary product, filtered from the milk of lime, is to be regarded as hydrated *sulphuret of calcium;* it has the property of rendering hair so loose in the skin, that it may easily be pulled out, as will appear if a piece of calf-skin is softened in it for some time.

Experiment.—By pouring one ounce of the liquid muriate of antimony into ten ounces of hot water, a decomposition and turbidness are produced, as in the case of the solution of bismuth; the precipitate is *oxide of antimony* combined with a little muriatic acid. Wash it several times with water, by settling and decanting the liquid, and then digest it for an hour with a solution of a quarter of an ounce of carbonate of soda in two ounces of hot water, whereby the muriatic acid is completely removed. The precipitate, being again washed, yields, when dry, a white powder of oxide of antimony. The same preparation is thus obtained in a moist way, as by igniting the metallic antimony. (§ 403.)

406. *Tartar Emetic* ($K\,O, \bar{T} + Sb\,O_3\,\bar{T} + 2\,H\,O$).—*Experiment.*—Boil in a porcelain dish two ounces of distilled water, and during the boiling stir in a mixture of one drachm of oxide of antimony, and one drachm of cream of tartar. When the liquid is half boiled away, filter it while boiling, and pour one half of it into one ounce of strong alcohol, but set the other half aside. In both cases you obtain a white salt, *tartar emetic;* in the latter case in the form of crystals, but in the former as a fine powder, because tartar emetic is insoluble in alcohol, and consequently is precipitated by it from its solutions. The process in this

case is a very simple one. Cream of tartar is an acid salt, that is, a combination of tartrate of potassa with free tartaric acid; this free tartaric acid combines with the oxide of antimony. Thus we obtain tartrate of potassa and tartrate of oxide of antimony, which unite together, forming a double salt, tartar emetic. The name indicates the medicinal application of this double salt; it is the most usual means of inducing vomiting. One grain of it, dissolved in half an ounce of sherry wine, forms the well-known *wine of antimony*. One ounce of tartar emetic requires fifteen ounces of cold water for solution.

407. *Sulphuret of Antimony.—Experiment.*—Add some sulphuretted hydrogen to a solution of tartar emetic in water: an *orange-coloured precipitate* of sulphuret of antimony ($Sb\ S_3$) is obtained, which becomes darker on drying. Thus the combination of antimony may be very well recognised, as no other metal yields a sulphuret of this colour.

We most frequently find antimony in nature having this composition; but the native sulphuret of antimony has quite another colour, namely, *steel-grey*, and in other respects likewise a very different exterior condition, as it occurs in heavy compact masses, which on the fractured surface appear as if they were composed of small shining needles or points. On account of this appearance, it has received the name of *prismatoidal antimony glance*. It melts even in the flame of a candle, and hence may be obtained from the different sorts of rock with which it is associated, merely by liquation. When pulverised, it forms a black-grey shining powder, which is employed by the farmer as a common remedy in the diseases of domestic animals. It is commonly, but erroneously, called *antimony*, by which term *sulphuret of antimony* is implied.

Experiment.—Boil a small quantity of pulverised grey sulphuret of antimony with a solution of potassa, let it settle, and add an acid to the decanted liquid: a brownish-red precipitate is produced, likewise sulphuret of antimony, which was dissolved by the potassa. This sulphuret of antimony (mixed with the oxide), which in the apothecary's shop is called *Kermes mineral*, is much more finely divided (§ 129) than the grey, and thereby acquires the red colour;

the division is still greater in the orange-coloured sulphuret, prepared from tartar emetic.

These three combinations, the orange, the red, and grey sulphurets of antimony, have quite a similar composition; they are one and the same body, only existing in different *isomeric* states.

A still higher sulphuret of antimony ($Sb\ S_5$) occurs in the pharmacopœias, under the name of the *golden sulphuret*, as an important medicine. It has an orange colour, and corresponds in its constitution to antimonic acid, as the grey or red sulphuret corresponds to the oxide of antimony.

For *Antimoniuretted Hydrogen*, see § 418.

408. *Preparation of Antimony.*—In order to separate metallic antimony from the sulphuret, it is only necessary to fuse it with iron, which has a greater affinity for the sulphur, and unites with it, forming sulphuret of iron. On cooling, the heavy metallic antimony settles at the very bottom.

409. *Alloys of Antimony.*—Of the alloys which antimony forms with other metals, that with lead, from which types are cast, deserves especial notice. Lead alone is much too soft to be employed for this purpose, but if from an eighth to a twelfth part of antimony is mixed with it, it acquires such a degree of hardness, that types cast from it may be used for printing many thousand times without losing their sharp edges.

ARSENIC, ARSENICUM (As).

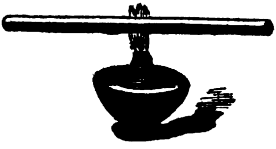
At. Wt. = 75.—Sp. Gr. = 5.7.

410. *Poisonous as arsenic*, is almost a proverbial expression, and it shows, in this respect, at least, that arsenic is well known, and in sufficiently bad repute. In fact, it is placed among the *metallic poisons*, and a very small quantity of it produces a fatal effect, unless antidotes are quickly administered. Happily, in recent times, a means has been discovered, in the *hydrated sesquioxide of iron* (*iron-rust*), by which most of the combinations of arsenic may be rendered, even in the stomach, insoluble, and thereby harmless. Before this remedy and the aid of the physician can be procured, it is well in cases of poisoning by arsenic, as in cases of poison generally, to administer milk, white of eggs, soap-suds, or

sugar. On account of the dangerous effects of arsenic, the *greatest care* must be taken, in experimenting with it, not to inhale its dust or vapour; the vessels that contain it must also be most carefully washed, and the water used for this purpose should be emptied into some place not accessible to domestic animals.

411. *Metallic Arsenic.*—Metallic arsenic is not unfrequently found in the earth, as a lead-grey ore, of strong metallic lustre. The artificially prepared metallic arsenic, which soon tarnishes and assumes motley colours in the air, and finally falls into a coarse grey powder, is kept on hand in the apothecaries' shops, under the name of fly-poison. If boiled with water, the film of oxidised arsenic dissolves, and a very poisonous liquid is obtained (fly-water). A fresh film of oxide is produced upon the metal which remains, and thus is very easily explained why, after a time, a new poisonous solution can again be prepared from it, without any perceptible decrease of the original powder.

Fig. 161.



Experiment.—Put a piece of arsenic of the size of a millet-seed into a glass tube, hold the latter by one end, and heat it; the arsenic volatilises at 356° F. (180° C.), and deposits itself on the upper portion of the tube as a *brilliant black mirror; the smell of garlic*, peculiar to the fumes of arsenic, being at the same time given off. These two tests are employed as very accurate for detecting the presence of arsenic in other bodies. Phosphorus, when exposed to the air, emits, likewise, the odour of garlic. If this indicates a similarity in these two bodies, the resemblance is rendered still more striking, by arsenic behaving very much like phosphorus in its combinations with other substances.

412. *White Arsenic, or Arsenious Acid* ($As\ O_3$).

Experiment.—Let the arsenical mirror obtained in the above experiment be heated once more, but in an *open* tube; it is converted into a vapour, which condenses on the colder parts of the tube, partly in small white crystals, partly as powder. Before the magnifying-glass these crystals appear as four-sided double pyramids (octahedrons); their constituent parts are arsenic and oxygen, and they are called *arsenious acid*, *white arsenic*, or ratsbane. When arsenic is spoken of in a popular sense, the white arsenic is always implied. It is obtained on a large scale, — *a*.) as a secondary product in the roasting of tin, silver, and cobalt ores; *b*.) as a principal product, by heating arsenical ores with access of air (in the arsenical furnaces in Saxony and Silesia). In both cases the arsenious acid passes off as vapour, with the smoke, which must therefore be conducted through long, horizontal chimneys, till it cools, and the arsenious acid condenses as a powder (*white arsenic*). White arsenic is often resublimed in some appropriate apparatus, and is then obtained as *amorphous* arsenious acid, in solid transparent pieces. These after a time become opaque and *milk-white*, like porcelain, without changing their constitution; another example that, even in solid bodies, atoms can alter their relative situations. (§ 280.)

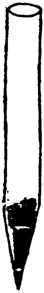
Arsenious acid is especially distinguished from the other metallic oxides by its solubility in water, which, indeed, is not very great, since one grain of it requires fifty grains of cold water, or from ten to twelve grains of boiling water, for solution; but it is sufficiently soluble to render these solutions exceedingly dangerous poisons. White arsenic is generally employed for killing rats, moles, and other troublesome house or field animals; for this purpose coloured arsenic only should be purchased, as the white arsenic looks very much like sugar or flour, and might easily be mistaken for them. In order to prevent its being carried off, it is best to strew powdered arsenic over broiled rinds of pork, or broiled fish, nailed upon boards. If the poison is put in stables, the fodder-troughs should be carefully covered over, that the poisoned rats may not vomit the poison into them.

Arsenious acid, like the perchloride of mercury, prevents the decay of organic substances; therefore the skins of animals intended for shipping are rubbed with arsenic upon the flesh side.

Arsenious acid readily gives up its oxygen in the heat to other bodies; for this reason it is added by glass-makers to melted glass, to convert its black or green colour into yellow. It acts like black oxide of manganese (§ 297); namely, it oxidises the protoxide into sesquioxide of iron. A solution of white arsenic and mercury in nitric acid is used by hatmakers to remove the shining smooth coating from the fur of hares.

413.. *Reduction of White Arsenic.*

Fig. 162.



Experiment.—Draw out a glass tube into a point, introduce into it a very little arsenious acid, and put upon it a splinter of charcoal; then heat the tube to redness in the flame of a spirit-lamp, first at the place where the charcoal lies, and afterwards at the pointed extremity of the tube; the glass becomes coated on the inside above the charcoal with a black *metallic mirror*, because the oxygen is withdrawn from the vapours of the arsenious acid while they pass over the glowing charcoal. This is one of the surest methods of detecting small quantities of arsenic.

414. *Combinations of White Arsenic with Bases.*

Experiment.—If ten grains of arsenious acid and twenty grains of carbonate of potassa are heated with half an ounce of water, the arsenic very readily dissolves, and a solution of *arsenite of potassa* is obtained.

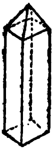
a.) Add gradually to one-half of this liquid a solution of fifteen grains of blue vitriol in half an ounce of hot water; a yellowish-green precipitate soon subsides, which, on drying, passes over into a dark green. This *arsenite of oxide of copper* occurs in commerce under the name of *Scheele's green.*

b.) The other half of the solution is likewise mixed in a flask with a solution of fifteen grains of blue vitriol in half an ounce of water, and then acetic acid (concentrated vinegar) is added as long as effervescence continues; the whole is then boiled for five minutes, after which the flask is put in a basin of hot water, that the cooling may take place *very slowly.* We obtain in this way, after twenty-four hours' repose, a double compound of arsenite and acetate of copper, which, on account of its splendid green colour, is extensively used as a pigment. Of its numerous names, those most known are

Schweinfurth green, *vert de mitis*, and *Vienna green*. *This colour is as poisonous as white arsenic;* hence extreme caution in the use of it cannot be too strenuously urged. It may even prove dangerous as a green paint for rooms, since, under some circumstances, volatile combinations of arsenic are formed from it, and mix with the air.

415. *Arsenic Acid* ($As\ O_5$).—If arsenious acid is boiled with nitric acid, it takes from the latter two additional atoms of oxygen, and becomes *arsenic acid*. The same acid is obtained, combined with potassa, by fusing together arsenious acid and nitre. The *biarseniate of potassa* thus produced, which crystallises in beautiful four-sided prisms, has hitherto been consumed in immense quantities in calico-printing, not so much to produce colours as to prevent their formation on certain parts of the texture.

Fig. 163.



416. *Sulphuret of Arsenic.—Experiment.*—Dissolve some grains of arsenious acid in boiling water, and add to the solution sulphuretted hydrogen; a precipitate of *yellow sulphuret of arsenic* ($As\ S_3$) is formed, three atoms of sulphur replacing three atoms of oxygen. In this way arsenic may easily be detected in liquids, and separated from them. The salts of cadmium and oxide of tin are the only ones, except arsenic, which give a yellow precipitate with sulphuretted hydrogen.* Sulphuret of arsenic is redissolved by hydrosulphuret of ammonia.

Sulphuret of arsenic also occurs native, and is called *orpiment*, or king's yellow, and was formerly used as a yellow pigment; but it is earnestly advised never to employ this colour in the painting of rooms, as it evolves upon lime walls an exceedingly poisonous gas (*arseniuretted hydrogen*). A sort of yellow arsenic, having the colour of yellow wax or porcelain, is also prepared in arsenical works by the sublimation of white arsenic with a little sulphur. This consists principally of arsenious acid, and contains but a small quantity of sulphuret of arsenic.

A combination of arsenic with one atom less of sulphur ($As\ S_2$), which is sometimes transparent, like ruby-red coloured glass, and sometimes opaque, like brownish-red porcelain, has received the name *Realgar*, or *red sulphuret of arsenic.*

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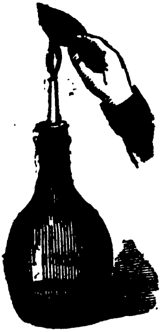
* The salts of antimony are precipitated of an orange-yellow colour by sulphuretted hydrogen.

Preparation of Arsenic.—Arsenic is most frequently found combined with sulphur and iron, as *arsenical pyrites.* Most of the white arsenic is prepared from this ore by roasting it in a reverberatory furnace, and, as already mentioned, condensing in poison-towers the fumes containing arsenious acid. The iron and sulphur are oxidised at the same time with the arsenic; but the oxidised iron remains behind, and the oxidised sulphur ($S\ O_2$) escapes with the smoke into the air.

417. *Arseniuretted Hydrogen Gas* ($As\ H_3$).—*Experiment.* —Introduce into a small flask diluted sulphuric acid and some pieces of zinc, and let the hydrogen which is evolved escape through a tube drawn out to a point, and *after some time* ignite it (§ 85); you obtain in this manner a hydrogen-lamp. If you hold a glazed porcelain capsule for a few moments in the flame, you will perceive upon it only a circle of small drops of water, which form during the combustion of the hydrogen, and condense on the cold portion. If you now dip a piece of wood into Schweinfurth green, so that only a little of it shall remain adhering to the wood, and introduce it into the flask, the flame, after the gas has been rekindled, will present a bluish white appearance, and will deposit on the porcelain held in it a *black* or *brown shining spot* (mirror); this mirror is metallic arsenic. Like sulphur and phosphorus, arsenic also will combine with hydrogen, forming a kind of gas, which, in company with the free hydrogen, escapes and burns. The flame is cooled by a cold body below the temperature which arsenic requires for burning; hence the latter condenses on the porcelain, just in the same way as carbon or soot is deposited on it when held in the flame of a candle. The carbon separates as a light, pulverulent body, arsenic as a coherent mirror. This incredibly sensitive test is called, after its inventor, *Marsh's arsenical test.* It follows from the previous remarks that care should be taken not to inhale the escaping gas, particularly the unburnt gas; but here more than ordinary caution is ne-

Fig. 164.



cessary, as arseniuretted hydrogen is a *most poisonous gas*, and one to which some chemists have already fallen a sacrifice.

418. *Antimoniuretted Hydrogen.—Experiment.*—Repeat the same experiment, substituting tartar emetic for Schweinfurth green; black spots are in this case also deposited on the porcelain, but they are darker, and often have a sooty appearance; they consist of *metallic antimony*. To distinguish spots of antimony with certainty from spots of arsenic, drop upon them a solution of chloride of lime; the spots of antimony remain unchanged, while the arsenical mirrors dissolve immediately.

Antimony and *arsenic* are the only metals which combine with *hydrogen;* they comport themselves in this respect like the metalloids; they may be regarded as the link, the bridge, which joins the territory of the non-metallic bodies or metalloids with the metals.

RETROSPECT OF THE THIRD GROUP OF THE HEAVY METALS.

1. The metals chromium, antimony, and arsenic, together with the previously-mentioned rarer metals, cannot decompose water; therefore concentrated acids must be employed for their solution.
2. Their lower degrees of oxidation comport themselves sometimes like bases, and sometimes like acids, but the higher only as *acids*.
3. These metals occur most frequently in nature combined with sulphur.
4. Antimony and arsenic are precipitated from their solutions as sulphurets by sulphuretted hydrogen, but are redissolved by hydrosulphuret of ammonia. Chromium is not converted into a sulphuret by sulphuretted hydrogen.
5. Antimony and arsenic can, like the metalloids, unite with hydrogen, forming gaseous compounds.

RETROSPECT OF ALL THE METALS.

Metals.

1. All metals have a peculiar *lustre*, are *opaque*, and the best *conductors* of heat and electricity.
2. Most of the metals will *crystallise* on cooling slowly (most commonly in cubes).

3. All the metals are *fusible*, but at very different degrees of heat; many of them, also, may be *volatilised*.

4. All metals can combine with *oxygen*, *sulphur*, and *chlorine*.

5. They likewise combine with each other when they are fused together (alloys).

Metallic Oxides.

6. Most of the metals form *basic oxides* with oxygen. Almost all the metallic oxides are insoluble in water.

7. Many metals possess one known *degree* only of *oxidation*, but most of them have two, some, indeed, three, four, and even five degrees of oxidation. The highest comport themselves as acids.

8. Metallic oxides may be *prepared* from the metals:

a.) By exposure to moist air.
b.) By heating with access of air.
c.) By decomposition of water at the ordinary temperature.
d.) By decomposition of water at a red heat.
e.) By decomposition of water with the aid of an acid, and precipitation by a strong base.
f.) By treating with concentrated acids, and precipitation by a strong base.
g.) By heating with nitre or chlorate of potassa.

9. The metallic oxides may be *deoxidised* or *reduced* to metals:

a.) By mere heating (noble metals).
b.) By heating with charcoal.
c.) By heating in hydrogen gas.
d.) By a more electro-positive metal (having a greater affinity for oxygen).
e.) By the galvanic current.

Metallic Sulphurets.

10. The sulphurets of the light metals are soluble in water, those of the heavy metals are, on the contrary, insoluble.

11. A metal has commonly as many degrees of sulphuration as of oxidation.

12. The metallic sulphurets may be *prepared*,—

a.) Directly by rubbing or melting together sulphur and a metal, or by heating the metal in the fumes of sulphur.
b.) By adding sulphuretted hydrogen or hydrosulphuret of ammonia to a metallic oxide or salt.
c.) By heating metallic sulphates with charcoal.

13. Sulphur may be expelled from the metallic sulphurets,—
a.) By heating them with access of air (roasting).
b.) By a more electro-positive metal.
c.) By heating in steam.
d.) By heating with strong acids.

Metallic Chlorides.

14. Most of the metallic chlorides may be crystallised, and are soluble in water.

15. As a general rule, a metal combines in as many proportions with chlorine as it has degrees of oxidation.

16. Metallic chlorides *are prepared,*—
a.) By bringing the metals or metallic oxides into contact with chlorine.
b.) By dissolving metals in muriatic acid.
c.) By dissolving metals in aqua regia.
d.) By double elective affinity, on mixing metallic chlorides with oxygen salts.

17. Chlorine may be *separated* from the metals,—
a.) By mere heating (the noble metals only).
b.) By heating in hydrogen gas.
c.) By a more electro-positive metal.
d.) By a stronger acid, for instance, sulphuric acid.

The Oxygen Salts.

18. Every acid usually forms a salt with every metallic base; hence, there is an infinite number of salts.

19. Suboxides must receive oxygen and superoxides part with it before they can combine with acids.

20. Most of the salts may be crystallised, sometimes with and sometimes without water of crystallisation.

21. The salts behave very differently towards water; some dissolve in it very easily, others with difficulty, and others not at all.

22. Salts may be *prepared*,—

a.) By exposing metals to the air.

b.) By dissolving them or their oxides in acids.

c.) By decomposition of the metallic sulphurets with acids; also by a spontaneous weathering of the metallic sulphurets.

d.) By mutual decomposition by means of predisposing simple or double elective affinity.

23. Many of the salts, by mere heating, lose their acids, which either escape (carbonic acid), or burn away (organic acids).

24. The salts, like the oxides, may be reduced to metals. If this is effected by ignition with charcoal, it is necessary to superadd a strong base (carbonate of soda, lime), which attracts the acid from the salt.

Occurrence of Metals in Nature.

25. The metals principally occur native in five forms, viz.: 1. uncombined, or *massive;* 2. combined with *sulphur*, as pyrites, glance, and blende; 3. with *arsenic*, as arseniurets; 4. with *oxygen*, as oxides; 5. with *oxygen* united with *acids*, as salts.

Of the best known metals, the following occur the most frequently:

1. *Pure.*
Gold,
Platinum,
Silver,
Bismuth,
Mercury,
Arsenic.

2. *As Sulphurets.*
Lead,
Antimony,
Copper,
Silver,
Mercury,
Arsenic,
Iron,
Zinc.

3. *As Arseniurets.*
Cobalt,
Nickel,
Silver,
Iron.

4. *As Oxides.*
Manganese,
Tin,
Iron,
Chromium,
Zinc,
Uranium,
Copper.

5. *As Salts.*
Potassium and Sodium,
Barium and Strontium,
Calcium and Magnesium,
Aluminium,
Zinc and Iron,
Lead and Copper.

Classification of the more common Chemical Elements.

It is very difficult so to classify the chemical elements,—so to bring them, as it were, into rank and file,—as to present at the same time a correct idea of their external and internal properties, and of their affinities for each other. In the following scheme, the two elements which are the most dissimilar, the most opposed,—namely, the most electro-negative (most acid), *oxygen*, and the most electro-positive (most basic), *potassium*,—form the two final members of the series; then the former is succeeded by those bodies which comport themselves like oxygen in their properties and combinations, while potassium is followed by those similar to itself. At the junction of the two series, the undecided elements are found —those comporting themselves sometimes negatively and sometimes positively. If it is a law in chemistry, *that bodies combine together so much the more eagerly the more dissimilar they are to each other*, while bodies similar in their properties show at most only a very slight inclination to combine, then this scheme may present to us at the same time a probable idea of the affinities of the elements for each other. *Those bodies most remote from each other in the series have a great desire to combine, while those the nearest to each other have but little or no desire to unite.* Thus, oxygen *most* readily desires to unite with potassium, next with sodium, next with calcium, barium, and so on; it comports itself most indifferently towards fluorine. Potassium, on the other hand, shows the greatest affinity for oxygen, then for the salt-formers, sulphur, &c.; but the least affinity for its neighbours and kindred, sodium, barium, &c. Let it be distinctly understood, however, *that this scale of affinity is a very fluctuating one*, and is subject in many cases to important modifications.

—	+
Oxygen	Potassium
Fluorine	Sodium
Chlorine	Barium and Strontium
Bromine	Calcium and Magnesium
Iodine	Aluminium
Sulphur	Chromium
Selenium	Manganese
Phosphorus	Iron
Nitrogen	Zinc
Carbon	Nickel and Cobalt
Boron	Lead and Bismuth
Silicon	Copper
Arsenic	Mercury
Antimony	Silver
Tin	Platinum and Gold

Negative elements, or those forming preferably *acids*.

Undecided elements, forming sometimes *bases*, and sometimes *acids*.

Positive elements, or those forming preferably *bases*.

Hydrogen.

±

PART II.

ORGANIC CHEMISTRY.

VEGETABLE MATTER.

419. An inscrutable wisdom has given to the seed the power of germinating in moist air, and of growing up into a plant, which puts forth leaves, flowers, and fruit, and then perishes and disappears. Germination, growth, flowering, fructification, and decay are the principal stages of existence through which plants have to pass. When they have produced seeds—that is, new bodies capable of life—they have fulfilled their destiny, and their course then tends downwards to decay. Whether they live only one short summer, or survive hundreds of years, the general principle remains essentially the same.

The Divine agency which effects these changes, and calls forth the phenomena of life in the vegetable world, is, in its essence, wholly unknown to us. A particular name, *vital power*, has, indeed, been given to it, but from this we derive no clearer conception or understanding of it. Its operations are conducted in such a mysterious manner, that it is not probable that the vague speculations of the inquiring mind on this point will ever lead to bright or clear ideas here below. We feel, indeed, the rushing of the vital current in the joy which penetrates us when in the spring this force causes the buds to expand, and covers the earth with showers of blossoms, as well as in the melancholy which seizes upon us when in the autumn the withering of the leaves announces to us its departure; but whence this force comes, and whither it goes, and how it calls forth, as it were by magic, the wonders of the vegetable world, we are, indeed, absolutely ignorant. That only which it produces, and from which it was produced, are comprehensible to our senses.

420. There are two ways open to the inquirer, by which he may gain a partial insight into the mysterious workshop of vegetable life:—1st, that of *observation*, which, by the aid of the microscope especially, has led to a very accurate knowledge of the structure of plants, and of the *changes* which their separate parts (organs) undergo during their growth; 2nd, that of *chemical experiment*, by which the constituents of plants, their food, and some of the *transformations of matter* occurring during the growth of the vegetables, have been discovered. The knowledge acquired in these two ways of the inward and outward changes which plants undergo during their existence, is called *vegetable physiology*.

421. There are generated in plants during their growth various independent substances which in many cases we can distinguish from each other even by their aspect and taste. Grapes, carrots, and many other fruits and roots, have a sweet taste; they contain *sugar*. The branches and leaves of the grape-vine have a sour taste; they contain an *acid salt*. Those of the wormwood have a bitter taste; they contain a peculiar *bitter principle*. The latter emit also a strong odour, which proceeds from a *volatile oil*. In the seeds of the different species of grain, and in the tubers of the potato, we find a mealy substance, *starch;* in the seeds of the rape and of the flax-plant a viscous juice, *fat oil*. From the cherry and plum-trees exudes a mucilaginous substance, which is soluble in water; from the firs and pines a similar substance, but which is insoluble in water; the former we call *gum*, the latter *pitch*. The magnificent colours of flowers proceed from a *colouring matter;* the noxious effects of poisonous plants from *vegetable bases*, &c. These substances are called by the general name of *proximate constituents of plants*. Many of them are to be found in almost *every* plant, while others occur only in *particular* species of plants.

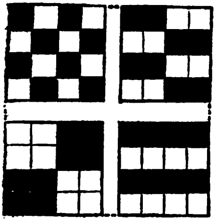
We cannot *imitate* by art the workings of nature in living plants, as we were able to do most perfectly in inorganic chemistry. The chemist, by chemical analysis, has, indeed, determined with the utmost accuracy of what elements the proximate constituents of plants are composed, and in what proportions by weight; but he has never yet succeeded in reconstructing these constituents from their elements.

422. Unripe grapes taste sour, ripe ones sweet; therefore we conclude that during the ripening the acid of the grapes has been converted into sugar. Common barley tastes mealy; if suffered to germinate it acquires a sweet taste, because during germination a portion of its starch is converted into sugar. Similar changes occur in every living plant; indeed, they frequently take place when the vital power has become extinct in the plant. Potatoes, for instance, become sweet by allowing them to freeze; all the starch of the germinated barley is converted into sugar by adding water to it, and letting it remain for some hours in a warm place. That which is thus produced by the vital activity of the plants, or by cold or heat, namely, *the transformation of one vegetable substance into another*, we are also able to effect by various other means. Art in this respect can indeed do more than nature, since it produces combinations—for instance, alcohol, pyroligneous acid, and many other compounds—which we never find ready made in the living plants. The number of these combinations may be increased almost innumerably by the aid of inorganic bodies, such as strong acids and bases, chlorine, &c.;—letting these operate upon vegetable substances, which are thereby changed in an infinitely varied manner, and transformed into new bodies. Thousands of such new combinations have been discovered within the last twenty years; our posterity will probably count them by millions.

423. If you ask what are the elements of which the proximate constituents of plants are composed, the answer is, the four following are the principal ones—*carbon, hydrogen, oxygen*, and *nitrogen*, which are therefore called *organogens*. Many of the vegetable tissues contain all the four elements (C H O N), and are called *nitrogenous* compounds; but others, and by far the largest proportion, contain only the first three elements (C H O), and are called *non-nitrogenous* compounds. From these few elements, with the addition of small quantities of sulphur, phosphorus, and some inorganic salts, the Creative Power is able to produce the countless multitude of plants which cover the surface of our earth.

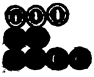
424. If it is obvious, from this simple constitution, that

the great variety of vegetable matter does not depend upon the number of the constituent parts, we must presume that this variety is owing to the different ways in which these four elements are joined together and combined with each other. And such is indeed the fact. It has already been mentioned (§ 274), that in the isomeric compounds, that is, in such as possess the same composition, but not the same properties, a different arrangement of the atoms is to be supposed; in the same manner as in a chess-board, where the white and black squares may be grouped together, either 2 and 2, or 3 and 3, or 4 and 4, &c. This variety in the grouping of the atoms, which happens only as an exception among inorganic substances, occurs as a general rule among organic compounds; and it has here so much the larger scope, because always three or four, and sometimes even more elements, are present, which enter into combination with each other, while, in the department of inorganic chemistry, commonly only two elements unite with each other; and likewise because it is a law in organic chemistry, *that the atoms of the elements do not unite singly, as is the case with mineral substances, but always in groups; namely*, 2, 3, 4, 6, 8, 10, *or more atoms of one element, with any number of atoms of the other elements.*



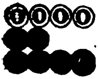
Organic substances have, therefore, an incomparably *more complicated constitution* than the inorganic compounds, as the following examples show:

Fig. 165.



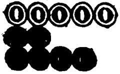
From the well-known amber, a peculiar acid, *succinic* acid, is obtained, which consists of four atoms of carbon, two atoms of hydrogen, and three atoms of oxygen, and has accordingly the formula $C_4 H_2 O_3$ (see Fig. 165).

Fig. 166.



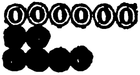
If one atom of oxygen is added to this, we have the constitution of *malic acid* $= C_4 H_2 O_4$ (see Fig. 166).

Fig. 167.



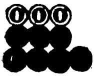
If one more atom of oxygen is added, that of *tartaric acid* $= C_4 H_2 O_5$ (see Fig. 167).

Fig. 168.



And by adding yet another atom of oxygen, that of *formic acid* = $C_4 H_2 O_6$ (see Fig. 168).

Fig. 169.

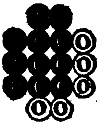


But, on the other hand, if one atom of hydrogen is added to the succinic acid, which was the starting-point, the constitution of *acetic acid* is obtained = $C_4 H_3 O_3$, &c. (see Fig. 169).

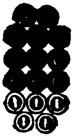
If we are not yet able to produce all the transformations as they are here given, yet the possibility of succeeding at some future time cannot be doubted.

Sugar, starch, and wood have precisely the same constitution, namely, $C_6 H_5 O_5$; they are *isomeric*. If we imagine these three elements grouped together in different ways, as, for instance,

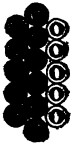
in sugar:
Fig. 170.



in starch:
Fig. 171.



in wood:
Fig. 172.



then we can form an idea how one and the same quantity of the same elements may combine, forming such very different bodies; and it would not now excite any great astonishment, if, on further investigation, hundreds of different substances of the same constitution should be discovered, since, by mere transposition of the above sixteen atoms, more than a hundred different arrangements or groupings may be produced.

425. The *instability* of organised substances, which has already been referred to, is now simply explained by these complex proportions of the atoms. They are like complicated machinery. In the spinning-wheel we have one wheel, one spindle, and one band; but in a spinning-machine, hundreds of wheels, spindles, and bands, all connected together into one whole. Now, as in complicated machinery, a wheel is more likely to come off, a spindle to bend, a wire to break, thereby causing a greater disturbance throughout the whole of the machine than can possibly happen in the simple spinning-wheel, so also complex organic bodies are much more

liable to disorganisations and changes than the more simple inorganic bodies. For if in the former only one of the many atoms leaves, or even changes, its place, or if another atom, whether of the same or of a different element, is added to it, the body at once ceases to be that which it was, and becomes a new peculiar compound. The familiar terms combustion, ignition, singeing, charring, rotting, decaying, fermenting, curdling, growing musty and sour, bleaching, fading, &c., are all *chemical metamorphoses* of the kind referred to, and it is well known that these metamorphoses are peculiar to animal and vegetable substances.

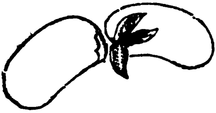
The sources from which the vegetable world derives its four fundamental substances (carbon, hydrogen, oxygen, and nitrogen), and the form in which it receives them, will be treated of more fully at the close of this part.

I. VEGETABLE TISSUE.

426. *Germination of Seeds.*—The vital force slumbers in the seed; it is called into activity by moisture and heat.

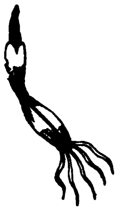
Experiment.—Pour water over some beans, and let them remain in a moderately warm place, till the germs burst forth, and the swollen seeds divide into two parts. If we now examine them closely, we shall perceive at the extremity of each seed, where the germ appears, two delicate white leaflets; from these, as the plant continues to grow, the stem and leaves are developed, while the other extremity of the germ forms into a root. The solid mass of which these young organs consist is called *vegetable tissue;* it consists of variously-formed cavities, which are filled with a colourless liquid, the *sap*. If the bean-plant is exposed to the action of light, a green colouring matter *(chlorophyll)* is produced in the sap; but this substance is not formed in the roots, since they are screened from the light by the surface of the earth. The two lobes of the bean *(cotyledons)* gradually disappear as the development of the plant advances; they serve as its first nourishment. The embryo of most plants is furnished with a pair of cotyledons *(dicotyledonous)*.

Fig. 173.



Experiment.—Barley, when caused to germinate in the same manner, puts forth only a single embryo, from which first the leaves and then the stalk are developed. All our grasses and bulbous plants germinate in this manner (*monocotyledonous*). If you pour off the water from the barley when the seeds are swelled and thoroughly steeped, and then put it in a cool place, piled up in heaps, you can, by occasionally turning it, so retard and regulate the growth that the radicles only will sprout forth. If you now arrest further vegetation by quickly drying the grain in a warm oven, the brewers' *malt* is obtained. The rootlets may be easily rubbed off after drying; they yield an excellent manure, and consist principally of vegetable tissue rich in potassa and other salts, which salts, during the process of germination, have passed from the grain into the radicle.

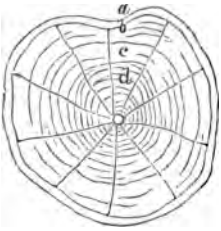
Fig. 174.



427. *Vegetable Tissue.*—All the cells and vessels of plants are composed of vegetable tissue. This substance is to plants what bones, flesh, and skin are to the animal body; it forms the solid mass of all vegetable organs, and consequently imparts to plants their shape and firmness; it forms the ducts or veins of the plants, through which the sap circulates. We find it very finely ramified, tender, soft, and easily digestible in the young leaves, flowers, and stems, and in the so-called pulp of fruit and roots, as apples, plums, carrots, &c.; hard and indigestible in straw, wood (*woody tissue*), and in the husks of grain (*bran*); hardened like stone in the stones of plums, cherries, and peaches, and in the shells of nuts; light, porous, and elastic in the pith of the elder, and in cork; lengthened and pliant in hemp, flax, and cotton.

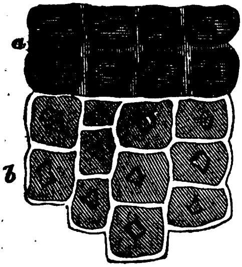
428. The transverse section of the stem of a tree illustrates the influence which age exerts upon the vegetable tissue, and how this tissue varies in one and the same tree. Inside the *bark* (*a*) lies the ***inner fibrous bark*** (*b*), which consists of lengthened tubes, and is peculiarly adapted to supply the place of veins in the tree. Here the sap principally circulates, and therefore a tree will die when the inner bark is girdled, whilst (as seen in many hollow trees) the

Fig. 175.



tree will live on if only the inner and outer bark remain, though the wood itself is entirely rotten and gone. From the inner bark towards the exterior is deposited every year a new layer of bark, and towards the centre a new layer of wood (annual circles). The light and whiter wood, lying next the inner bark, is called *sap-wood (c)*; but this, by the annually increasing compressure, becomes denser and more solid, and then it is called *heart-wood (d)*. The latter is usually darker, and is frequently impregnated with colouring matter (red-wood). The annexed figure will give an idea of the artistical internal structure, which is manifest even in apparently simple dense wood, when viewed under a strong magnifying glass. It represents the transverse section of a pine bough, the portion marked *a* representing young ligneous cells, those marked *b* the matured cells.

Fig. 176.



Most plants contain in the inner and outer bark a substance which has an astringent taste, is soluble in water, and which is known by the name of *tannin*, or *tannic acid*.

429. *Linen* is the inner bark of the flax-plant. During the process of *retting*, the outer bark, by the long-continued influence of moisture and air, passes over into decay, and then, after rapid drying, may be rubbed off by bending it backwards and forwards (*breaking*); but the filaments of the inner bark, which do not so readily decay, remain behind, and after being parted into their finest fibrils, and arranged parallel by the so-called *heckling*, form the well-known *flax*. The tow, which falls off during this process, consists of tangled fibres of the inner bark.

Flax has a grey colour, because it contains a grey colouring matter, which is not soluble in water and lye, though it becomes soluble in lye by exposing the flax, the thread spun, or the linen woven from it, during a long time, to the action of light, water, and air. This is done in the bleaching-yard by spreading it on the grass (*grass bleaching*). The colouring matter, hereby altered and rendered soluble, is removed from time to time by boiling with lye. Bleaching may be accomplished more rapidly by the application of chlorine, which, on account of its very strong affinity for hydrogen, attracts hydrogen from all organic substances, whereby they become colourless and soluble (*chlorine bleaching*). The question here occurs, Why is it that in these two bleaching processes the colouring matter alone, and not the vegetable tissue at the same time, is decomposed? The reason is, because the colouring matter consists of four elements (C H O N), but the vegetable tissue of only three elements (C H O); according to § 425, the more complicated substance, consisting of four elements, is more readily and rapidly decomposed than the less complicated substance, consisting of three elements. If, when the linen has become white, the bleaching were still continued by either of these methods, the vegetable tissue would then be decomposed and become rotten; a case which often occurs when linen, cotton, or paper is treated too long, or with too strong a solution of chlorine.

430. *Bast.*—Soak the bark of the lime-tree in water till the outer bark is decomposed, and has become brittle; when it is dry the inner fibrous part of the bark can be peeled from it, and it then forms the *lime bast*, used for tying up plants. The outer covering of the trees, which is commonly, but erroneously, called bark, consists by no means of the proper bark alone, but of two essentially different parts, which have grown very closely together; the external layer is the proper bark (*epidermis*), the inner is the bast (*liber*).

431. *Cotton* consists of delicate hollow hairs, which form in the cotton-plant in considerable quantities around the seeds. As it exists in nature it is beautifully white (except the Nankin cotton, which is yellow), and consequently requires no bleaching. When, however, cotton thread or cotton fabrics are bleached, it is merely in order to remove the oily, sweaty, and mealy substances (*weaver's glue, &c.*) which have become attached to them during spinning and weaving. This is now usually effected by boiling with soda-lye or milk of lime, or immersing them in a weak solution of chloride of lime. The lime which remains adhering is then removed by exceedingly diluted acids (*acid bath*), and the acid, in its turn, by rinsing in water.

It is well known how important the above-mentioned sorts of pliant vegetable tissue are, on account of their application for making thread, twine, and fabrics of every variety; we clothe ourselves in woody fibre, we write and print upon it, we build our houses of it, &c.

432. *Vegetable Tissue and Water.—Experiment.*—Pour some lukewarm water over sawdust, and let it stand for a day; then squeeze out the liquid through a cloth and boil it; a slight turbidness will appear, and on longer standing a loose sediment will be deposited. Water does *not* dissolve the woody fibre, though it does the sap contained in it; in this sap, as in that of all other plants, there is always found a substance in solution, which is very analogous to the white of eggs, and which, like it, coagulates in boiling; it is called *vegetable albumen.* There are also contained in the liquid, separated from the albumen, various other substances in solution (mucus, gum, tannin, &c.), which are not precipitated by boiling. If the sawdust, after it has been dried, is treated with alcohol, this will also dissolve some substances (resin, &c.); and so also will ether, lye, and other liquids. Therefore, in the preparation of perfectly pure woody tissue, it must be treated with various solvents in order to remove all the constituents of the sap.

CHANGES OF VEGETABLE TISSUE.

a.) Changes of Vegetable Tissue by Acids.

433. Wood, when dipped in *sulphuric acid,* is charred; when in *nitric acid,* it is dyed yellow, and by longer immersion it is entirely decomposed, as has already been observed. (§§ 160, 173.) Sulphuric acid attracts from the woody fibre hydrogen and oxygen, which combine to form water, and then unite with the sulphuric acid; nitric acid yields oxygen to it, and consequently oxidises it. By very long continued treatment, all the carbon of the wood may finally be oxidised into carbonic acid, and all the hydrogen into water. Chlorine decomposes the vegetable tissue by abstracting hydrogen. (§ 429.) Diluted sulphuric acid operates very differently from the concentrated acid; if paper, linen, &c., are boiled for several hours with the former, the vegetable tissue is converted, first into gum, and finally into sugar.

Explosive Vegetable Tissue, or *Gun-Cotton* (*Pyroxylin*).—By exposing vegetable tissue (cotton, hemp, linen, sawdust, &c.) for a short time to the action of highly concentrated nitric acid, it acquires the remarkable property, like that of gunpowder, of igniting and exploding with great violence when touched by a lighted match.

Experiment.—Mix half an ounce of the strongest nitric acid (sp. gr. $=1.5$) with one ounce of strong sulphuric acid; pour the mixture into a porcelain mortar, or a cup, and press into it with the pestle as much cotton (wick-yarn, calico, printing-paper, &c.) as can be moistened by the acid. When the cotton has soaked for five minutes, it is to be taken out with a glass rod, put into a vessel containing water, and washed repeatedly with fresh quantities of water, until it no longer reddens blue test-paper. The cotton is then squeezed out with the hand, spread upon a sheet of paper, and dried in an airy place. It is dangerous to dry it upon a stove, as it easily takes fire.

If the *gun-cotton* thus prepared is struck smartly with a hammer upon an iron anvil, it detonates violently; when touched with a hot wire or a lighted match, it burns instantaneously, without leaving any residue; when fire-arms are loaded with it, it acts like gunpowder, but its explosive power is four or five times greater than that of the latter. Gun-cotton being, therefore, an exceedingly dangerous substance, the *greatest caution* is indispensable in conducting experiments with it, and only very small quantities should be used at once. Gun-cotton dissolves in ether into a sirupy liquid, which on spontaneous evaporation leaves the cotton behind in the form of a transparent film. This solution is called *collodion.* It is used instead of court-plaster, and for making small air-balloons, &c.

The chemical changes which cotton undergoes by immersing it in the above acid mixture consist chiefly in this, that it gives up a portion of its hydrogen and oxygen (as water), and receives instead nitric acid (consequently, nitrogen with much oxygen). Gun-cotton contains, therefore, *much more oxygen* than the common cotton, and likewise *nitrogen*, in chemical combination; the former causes the rapid combustion, while the latter, together with the gases formed by the combustion, causes the rapid explosion. The sulphuric acid co-operates only indirectly, by attracting and retaining the water contained in the nitric acid, and that which separates from the cotton.

b.) Changes of the Vegetable Tissue by Alkalies.

434. The effect of alkalies on vegetable tissues may readily be seen by wrapping a piece of quicklime in paper, and letting it remain there for some weeks, when the paper will become quite rotten. The farmer and the gardener, being well acquainted with this action, are accustomed to mix lime or ashes with couch-grass and other weeds, to accelerate their rotting and decay.

c.) Changes of the Vegetable Tissue by Heat, with free Access of Air.

435. That wood, &c., when heated with access of air is consumed, that is, is decomposed into carbon and water, has already been fully treated of in the former part of this work. *All vegetable substances are consumed in the same way, by means of the oxygen of the air.* If inorganic substances (salts and earths) are present, they, since they are not volatile, remain behind as *ashes.*

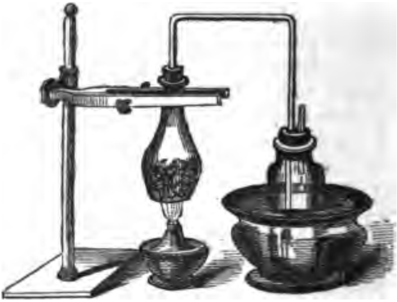
Vegetable, and likewise animal substances, can be consumed, not only by the oxygen of the air, but also by the oxygen of other bodies; as, for example, by that of oxide of copper, of chromate and chlorate of potassa, or directly by pure oxygen itself. If the water formed during the combustion is absorbed by chloride of calcium, and the carbonic acid by a solution of potassa, then, by the increased weight of the chloride of calcium and the potassa, the quantity of the water and of the carbonic acid may be ascertained, and from these the weight of the hydrogen and carbon which the consumed body contained may be calculated. That which is wanting in the weight of the original body under examination is the amount of oxygen which it contained. In this manner the three elements comprised in an organic body, carbon, hydrogen, and oxygen, may be very accurately determined; such an examination is therefore called an *elementary analysis.* If, in addition to the three above-named elements, an organic body contains nitrogen also, it escapes uncombined during the combustion in the form of gas, and can be collected and estimated by a special method of analysis. But on heating such bodies with bases having a strong affinity for water,—for instance, with hydrate of potassa or soda and lime,—then (with but few exceptions) the nitrogen contained in them escapes in combination with hydrogen, as ammonia, from which the contents of nitrogen can be accurately calculated.

d.) Changes of the Vegetable Tissue by Heat, the Access of Air being prevented.

436. *Imperfect Combustion of Wood.*—When wood is heated with insufficient access of air, as is the case, for instance, in most of our stoves, a portion of the carbon remains unburnt, and is deposited as *soot* from the gases which form the flame. Moreover, during the process, a portion of the burning carbon takes up only half as much oxygen as when there is an abundant supply of air, and there is formed, not only carbonic acid, but also carbonic oxide gas (fumes of charcoal). But, besides these compounds, other singular substances are formed, as is indicated by the peculiar smell of the smoke, and by the lustrous acid and resinous soot deposited upon the lower parts of chimneys. The products of the decomposition of vegetable tissue may be more clearly recognised if you heat the wood with entire exclusion of air.

Experiment.—Subject wood, as was described in § 119, to dry distillation; you obtain a great variety of products easily to be distinguished by characteristic properties:—1. *charcoal*, which, since it is not volatile, remains behind; 2. *illuminating gas*, a mixture of carburetted hydrogen, carbonic acid, and carbonic oxide gases; 3. *wood-vinegar*, a watery acid liquid; 4. *wood-tar*, a thick, brown, resinous liquid. The two former

Fig. 177.



substances have been already described, so that only the two latter remain to be more fully considered.

437. *Pyroligneous Acid or Wood-Vinegar.*—One pound of dry beech-wood yields nearly half a pound of pyroligneous acid. In its crude state it has a brownish-black colour, owing to the tar which it contains in solution, and a smoky odour, together with a very acid, disagreeable, smoky flavour. On account of its containing acetic acid, and its cheapness, it is now much used in the preparation of acetates, particularly such as are employed in calico-printing and dyeing; for instance, acetate of iron, of lead, of soda, &c.

Experiment.—Pour some wood-vinegar upon a piece of lean meat, and let it soak for a few hours; it can then be dried and packed without passing into putrefaction, as in a few hours it has experienced the same change, and acquires the same degree of firmness, usually produced by being suspended for months in the smoke (*rapid smoking*).

438. Wood-vinegar owes its antiseptic properties to a peculiar substance, which has received the name of *creosote* (flesh-preserver); one pound of pyroligneous acid contais about a quarter of an ounce of it in solution. Pure creosote is a colourless liquid, gradually becoming brown by age, and of an oily consistency; it has a strong smell of smoke, a very burning taste, and disorganises the tender skin of the tongue or the mouth, and, taken internally, is a powerful poison. Creosote is now frequently applied as a remedy for the toothache, when it is usually mixed with oil of cloves; but it must also be diluted with alcohol, in which it readily dissolves, as its action would otherwise be too corrosive. One drachm of water will dissolve one drop of creosote; this solution (*creosote-water*, or *aqua Binelli*), which acts upon flesh in the same manner as the pyroligneous acid, is employed as a sedative. The smoke which is formed in our stoves by the imperfect combustion of wood, or of coal, always contains fumes of creosote, to which is owing its peculiar smell, and its property of causing lachrymation. Everything which prevents complete combustion, such as a deficient draught of air, or moist fuel, must, accordingly, favour the formation of creosote, and render the smoke more irritating. Meat is most effectually cured by this

smoke, which is expressly generated for this purpose by burning green fagots, or obstructing the draught of air.

439. When pyroligneous acid is very slowly distilled, a spirituous, volatile liquid, very similar to brandy, first passes over, which is called crude *pyroxilic spirit.* The chief component of this fluid is a substance which, in its properties and changes, has great similarity to alcohol, or spirits of wine, though its constitution is different. On account of this similarity, it is called pyroxilic spirit (*hydrated oxide of methyle*).

440. *Wood-tar* is of a resinous nature; that is, insoluble in water, though soluble in alcohol; it is, moreover, very rich in carbon, as is in some degree indicated by its black colour. On distillation, it separates into a volatile oil (*oil of tar*), and into a non-volatile black pitch. (§ 576.) This separation takes place, also, but more slowly, when wood is smeared with tar; the pitch, hardening in the pores of the wood, then prevents the penetration of the water, and hereby, as by the creosote also contained in the tar, the decomposition of the wood by putrefaction is arrested (tarring and calking of ships, &c.).

The dry distillation of wood shows in a very striking manner with what extraordinary readiness organic substances may be decomposed and transformed into very remarkable new bodies. The wood has only to be heated in order to be resolved into an acid and a spirituous body, into oily and resinous substances, into illuminating gas and charcoal. And these are not all the products of the decomposition of wood. Besides the substances here mentioned, a dozen others, at least, have been discovered, which are generated simultaneously with them; and each of which may be converted by heating, by treating with acids, bases, chlorine, &c., into numerous other bodies. Here a great field opens for chemical investigation, a field which has, indeed, no bounds, and which must be so much the more extended, since *all vegetable matter, heated with exclusion of air, becomes charred and decomposed into products of combustion, but which are different in different bodies*, as is obvious in the dry distillation of tobacco in tobacco-pipes, of common coal, brown coal, &c.

441. *Imperfect Combustion of common Coal.*—Common coal and brown coal are formed from the plants of a former era, which were washed together in heaps during some revolution of the earth, and deeply buried beneath mud and soil. When common coal is heated with exclusion of air, we obtain, in the same manner as from wood,—1. charcoal (coke); 2. a combustible gas (illuminating gas); 3. an aqueous, empyreumatic liquid (tar-water); and 4. a resinous, black, viscid liquid (coal-tar).

The aqueous empyreumatic liquid obtained from common coal contains only a trace of vinegar, but in larger quantities a basic body—ammonia, combined with carbonic acid; it may, therefore, be employed as a manure, or for the preparation of sal ammoniac.

The *coal-tar*, which is now very generally employed for smearing over wood, iron, and the roofs of buildings, to protect them from moisture, may also, like wood-tar, be separated by distillation into a volatile substance (oil of coal-tar), and into a pitchy, non-volatile substance (artificial asphaltum); but the peculiar substances (kyanole, pyrrol, leucol, carbolic acid, rosolic acid, brunolic acid, naphthaline, &c.) contained in the latter are quite different from those of the former. Of these substances, *naphthaline*, a white, camphor-like body, has been examined most closely; but the names only of some of the new combinations resulting from these researches will here be mentioned, to show, alas! with what a flood of new and strange names this single substance has inundated chemistry. The following compounds are formed by the action of nitric acid upon naphthaline: nitronaphth-alase, -aleise, -alise, -ale, -esic acid, -isic acid, phthalic acid, phthalamide, &c.; by treating with chlorine: chloronaphtha-lase, -lese, -lise, -lose, &c.

442. A decomposition similar to that which coal undergoes during dry distillation must also be produced, perhaps, in many places in the interior of the earth, by volcanic heat, for we know that in many countries substances either issue from the earth or are imbedded in it, which have a very great similarity to the products of the distillation of coal, as is shown in the following arrangement:

Artificially produced from Coal.	Occurring Native in the Earth.
a.) *Illuminating gas.*	a.) *Inflammable gases* (sacred fire of the Bramins), issuing here and there from the crevices of rocks.
b.) *Oil of coal-tar.*	b.) *Naphtha*, oozing out of the earth in Persia.
c.) *Coal-tar.*	c.) *Mineral tar*, found in many places in Persia and France.
d.) *Artificial asphaltum* (coal-pitch).	d.) *Natural asphaltum* (pitch of Judea), found in the Dead Sea, and other Asiatic seas.
e.) *Ammoniacal empyreumatic liquid.*	e.) *Ammonia*, issuing in a watery vapour, associated with boracic acid, from the earth near Tuscany.
f.) *Coke* (C).	f.) *Anthracite* (C), like common coal, occurring in immense beds in the earth.

e.) *Changes of the Vegetable Tissue by Air and Water. (Decay and Putrefaction.)*

443. *Decay.*—When vegetable tissue—for instance, wood, leaves, straw, &c.—is exposed to the influence of the air, it imbibes moisture, and becomes gradually brown and rotten—it passes into *decay*. The chemical process which thus takes place very much resembles those changes which wood undergoes in combustion, except that it takes place far more slowly. What is effected by combustion in minutes, is effected by decay only in the course of years. By combustion, the constituents of the wood and the oxygen of the air are converted into carbonic acid and water; the same products are also formed on the decay of wood. In combustion, the hydrogen is oxidised more rapidly than the carbon; the same happens also in decay. This explains why wood, on combustion, as well as on decay, assumes a darker—first a brown, and then a black—colour. When proportionably more hydrogen passes off than carbon, the residue must necessarily, as the decomposition continually progresses, be richer in carbon, and consequently, as a general rule, also of a darker colour.

444. *Humus.*—The brown or black substance into which vegetable matter is converted by decay has received the name *humus*. As wood, which is only partially consumed, can be consumed still further, so also humus is gradually further decomposed, and in most cases, after complete combustion or decay, there is finally left only a small quantity

of non-volatile salts and earths,—*the ashes,*—which the wood has absorbed from the earth during its growth. If these two processes of decay are supposed to be going on in two distinct periods, then there are formed,—

in combustion,		*in decay,*	
from the *wood* in the 1st period,	water (much), carbonic acid, half-burnt wood;	from the *wood* in the 1st period,	water (much), carbonic acid, humus;
from the *half-burnt wood* in the 2nd period,	water (little), carbonic acid;	from the humus in the 2nd period,	water (little), carbonic acid;
there remain,	ashes.	there remain,	ashes.

Humus is identical with decaying Organic Matter.—In this acceptation it has for many years been known and valued in agriculture. Vegetable mould (humus) is the term applied to the upper black or brown layer of earth, which has been formed in forests by the decay of the leaves which fall off; the dark, fat, arable soil, containing much partially decomposed organic matter, is said to be rich in humus, while the dry, light soil, in which it is wanting, is said to be poor in humus. The farmer knows that, contrary to what happens in his woodlands, the humus diminishes in his fields, and so much the more rapidly as the crops are more abundant; he knows that fields rich in humus are, as a general rule, more fertile than those which are poor in humus. Therefore he seeks to restore to his land the humus consumed in vegetation by ploughing in straw and animal excrements (*manuring*), or fresh plants (*green manuring*), or by the alternation of plants which leave behind many roots in the soil (*fallow plants*) with such as are only feebly rooted (*grain*). On an acre of land which was cultivated with clover, several thousand pounds of roots remained behind in the soil; upon one cultivated with wheat or grain, only from one-fifth to one-sixth as much; it is therefore apparent, that in the former case from five to six times more humus must be generated by the decay of the roots than in the latter. The increase of fertility which the farmer thus aims at is, however, *by no means* to be ascribed to the humus alone, since the inorganic constituents (salts and earths) which are present in manure and in the soil have a *principal* share in it. (§ 611.)

If we consider the formation of *humus*, we shall at once perceive that various substances are included under this term; for its constitution alters every day, since a little of its carbon and hydrogen is every day oxidised and separated. We may easily conceive, that very old humus may contain as much again carbon as that which is recent, or even more. The ideas concerning humus became still more vague when chemists first thought of designating by this name other brown and black coloured substances, the products of the evaporation of vegetable juices or decoctions, or which were formed from wood, starch, sugar, &c., by boiling the latter with acids or alkalies. The term *humus* thus became, as it were, a foundling hospital, into which were brought all the substances formed from vegetable or animal matter, provided they were black or brown, and were insoluble, or nearly insoluble, in water. The humus generated by decay, as we find it in the soil, is now thought to be a mixture of several distinct brown substances, namely, of ulmine, humine, ulmic acid, humic acid, geic acid, crenic and apocrenic acids, which are produced consecutively, according to the above series, from vegetable matter. The two latter acids are soluble in water, and are partly the cause of the yellow or brownish colour which we perceive in the water of marshes or bogs; the other three acids are only soluble in water when alkalies are added; finally, the first two substances, ulmine and humine, can neither be made soluble by water nor by alkalies. Accordingly, by the general term *humus* we must understand a mass of brown decaying matter, partly soluble, partly insoluble, partly acid, partly neutral, which, with the uninterrupted presence of air, water, and heat, may be still further decomposed, and thereby *carbonic acid* and *water* evolved. Carbonic acid and water are indispensable to the nourishment of plants; hence, in a soil rich in humus, the plants will grow more vigorously, because they find there, and can absorb by their rootlets, more of these two nutritive substances than they could in a soil poor in humus. Humus exerts, moreover, a beneficial influence upon vegetation, because it loosens the soil by the development of carbonic acid, because it possesses the power of attracting water from the air, and of retaining it for a long time, and because, by means of the acids contained in it, it is able to abstract from the air, and also from manure, the third means of nutriment for plants, ammonia.

445. *Putrefaction.*—The decomposition of vegetable tissue takes place in a somewhat different manner when the air is entirely or partially excluded,—for instance, when the decomposition takes place *under water*, as we observe in ponds, bogs, marshes, and rivers.

Experiment.—Thrust a stick into the mud of a pond, and catch the bubbles which rise, in a bottle filled with water, and held inverted over them; when all the water is displaced from the bottle, close it up while under the water. Introduce a little water into the bottle, and afterwards a small piece of caustic potassa or quicklime, close it immediately, shake it a few minutes, and then remove the stopper under water; a part of the water will press into the bottle, because the bases have absorbed a portion of the gas. The gas absorbed was *carbonic acid.* If you now apply a burning match to the mouth of the bottle, and expel the remainder of the gas by pouring in water, it will ignite and burn with a blue flame. This is called *marsh gas* (light carburetted hydrogen gas); it consists of carbon and hydrogen, like the common illuminating gas, but it contains, compared with this, a smaller quantity of carbon, and therefore burns without giving a bright light. These two gases, carbonic acid and marsh gas, originated in the wood, leaves, branches, roots, &c., of the plants which sunk to the bottom of the water, and were there decomposed.

Fig. 178.

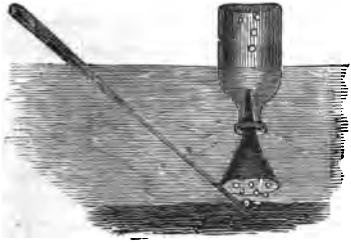
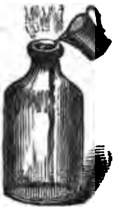


Fig. 179.



When oxygen is wanting, the hydrogen of the vegetable tissue combines with a portion of the carbon, while, if there is an abundant supply of oxygen, the hydrogen unites with the latter. Here, too, a substance similar to humus, and richer in carbon, remains behind; in ponds, as a black *mud,* in bogs, as *peat*. This kind of decomposition is called *putrefaction;* it is somewhat analogous to the change which wood undergoes on imperfect combustion *(charring, dry distillation)*, as is shown by the following arrangement:

In charring,		*In putrefaction,*	
the vegetable tissue is converted into	*a.*) illuminating gas, *b.*) carbonic acid, *c.*) partially burnt substances (tar, coke, &c.)	the vegetable tissue is converted into	*a.*) marsh gas, *b.*) carbonic acid, *c.*) partially rotted substances (mud, peat.)

446. Peat is formed from marsh plants, which slowly rot under water; every year a new vegetation arises, which, on perishing, sinks to the bottom, and thus, in the course of time, a morass is formed. The young peat consists of a brown, fibrous network, in which the separate parts of the plant may be clearly distinguished; but after a time it decomposes into a black, slimy mass, which may be cut into pieces of the shape of bricks. The old, black turf only smoulders away on burning, a proof that the hydrogen of the plants from which it was formed has mostly disappeared during putrefaction.

447. As above stated, carbonic acid is continually generated in the formation of peat; a portion of this carbonic acid remains in solution in the water, and this explains why the water which percolates through beds of peat into the earth, and reappears as springs in deeper places, often contains so much carbonic acid that it can be used as *mineral water* (acidulous springs). If the water during its course meets with rocks containing protoxide of iron, lime, magnesia, &c., it may, by means of its carbonic acid, dissolve small quantities of them. (§§ 237, 276.) In this manner many of the mineral waters occurring in nature originate, as, for instance, the celebrated Marienbad springs, &c.

448. Besides peat, we find two other vegetable substances in the earth, which are likewise used as fuel, on account of their richness in carbon,—*brown coal* and *common* or *pit-coal.* Both are the remains of a vegetation which covered the earth before it was inhabited by man. It is highly probable that they were formed from the vegetables and trees of a primeval age, when, by inundation, or some other violent revolution which the crust of the earth underwent, they were

buried under immense beds of sand and clay, and were there decomposed by a process similar to that of putrefaction, while the sand hardened into sandstone, and the clay into slaty clay or shale. In those places where the layers of earth were not sufficiently strong to prevent the escape of the carbonic acid and of the marsh gas, we often find, as, for instance, in many species of brown coal, the form of the wood so well preserved, that the annual rings may be distinguished in it (bituminous wood); but in other places the wood is transformed into a brown mass, which has a strong resemblance to humus, or peat (brown coal). But if the pressure of the superincumbent mass of earth was so strong as to prevent the escape of the gases formed during the decomposition of the imprisoned plants, they must necessarily have remained behind with the coal. This, together with the compressure of a weight of a layer of earth or stone, a thousand, perhaps several thousand, feet thick, accounts for the dense, compact, stone-like nature of many kinds of coal, especially of pit-coal, and also for their property of burning with a flame. Those gases which were condensed in the coal we obtain again, as illuminating gas and carbonic acid, when we heat the coal in a retort.

It is generally known that moist vegetable matter, as grass, hay, manure, &c., becomes hot, and is converted into a black, richly carbonaceous mass, when piled together in compact heaps. This *smouldering sort of carbonisation*, taking place here on a small scale, must occur also on a large scale, when, by some revolution in the earth, masses of plants are washed together in heaps, and covered over with mud; and this smouldering must be so much the more complete the greater is the pressure under which the decomposition takes place, and the longer the time occupied in effecting it. Pit-coal is usually found at greater depths in the earth, and between older layers of rocks (in the transition rocks), than the brown coal, which mostly occurs nearer the surface of the earth, between more recent layers of rocks (in the tertiary rocks); we, therefore, conclude that the formation of pit-coal commenced at an earlier period, and that of brown coal not till a later period. The extraordinary differences occurring in this process of decomposition, according to the *variety* of plants, and the co-operation of more or less water, heat, air, pressure, &c., are very evident in the extraordinary *variety* of the products formed. Many of the pit and brown coals burn with a vivid flame, others with a feeble one, and some without any; many melt in the heat, others crumble to a sandy powder; many yield but 1 per cent. of ashes, while others yield from 25 to 30 per cent., &c.

449. *Rotten White Wood.—Experiment.*—Put, during the summer, some sawdust, moistened with water, in a closed vessel, and let it stand for some months; the wood will gradually lose its firmness, and be converted into a *white, friable substance.* A splinter of wood will not continue to burn in the air of the vessel, since the air no longer contains free oxygen, but carbonic acid. The water, too, has disappeared: it has chemically combined with the woody tissue. A similar transformation frequently occurs in the interior of the trunks of trees, where the air cannot have free access; the well-known white rotten wood is formed in this way. When the air has free access, a brown substance (humus, ulmine) is produced, such as occurs in hollow elms, willows, limes, and other trees.

The decomposition to which wood is exposed by decay and putrefaction may be *retarded* and *checked,*—

1. By rapid drying, whereby the water of the sap is removed.

2. By steeping in water or steam, by which process the sap is dissolved and removed.

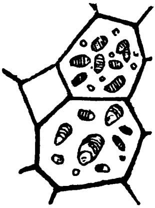
3. By smearing with bodies which prevent the penetration of the water; for instance, with varnish, tar, pitch, &c.

4. By impregnation with saline solutions, which act antiseptically; for instance, with corrosive sublimate (kyanizing), salts of lime, iron, &c.

II. STARCH, OR FECULA.

450. A MEALY substance, which is known under the name of *starch*, or *fecula*, is deposited in most vegetables, particularly at the period of ripening, from the juices with which the cells of the plants are filled.

Fig. 180.



It appears to the naked eye like particles of meal, but under a powerful microscope it is found to consist of small, generally regular grains or globules. Their position in the plant is shown in the annexed figure, which represents a section of some of the cells of a potato.

If a fresh plant is bruised and macerated in water, and the liquid then squeezed out, a large portion of the starch will pass with the juice from the vegetable tissue, and will settle, after standing quietly awhile, as a mealy mass. Potatoes, grain, and leguminous plants are very rich in starch.

451. *Potatoes.*—*Experiment.*—Rasp some potatoes on a grater, knead the pulp thus obtained with water, and squeeze it in a linen cloth; the *fibrous particles* of the cells remain behind, but the juice, together with a large portion of the starch, runs through. If you let the turbid liquid remain quiet for some hours, it becomes clear, because the heavier *starch* settles at the bottom. Now decant the liquid, wash the starch several times with fresh water, allowing it to settle each time, and then dry it in a moderately warm place.

Experiment.—Heat in a flask the clear liquid decanted from the starch; it becomes turbid when the heat approaches the boiling point, and, after boiling for a few moments, deposits a flaky, greyish-white substance, which is to be collected on a filter. It is the same substance already referred to (§ 432), *vegetable albumen*, characterised by its property of dissolving in cold and warm water, but of coagulating in boiling water. It contains nitrogen, which the starch does not.

Experiment.—Put some of the coagulated albumen upon a piece of platinum foil, and heat it over a lamp; it will burn and emit a very disagreeable empyreumatic odour. When starch is treated in the same manner, it also gives off an empyreumatic, but far less unpleasant smell. All nitrogenous substances comport themselves in this respect like albumen; all non-nitrogenous substances, like starch; therefore, when a piece of woollen cloth is singed, it diffuses a far more disagreeable odour than a piece of cotton or linen, because nitrogen is contained in the wool, but not in the cotton or linen.

A freshly-cut potato has a white colour, which, however, on longer exposure to the air, passes over to brown; a similar change takes place in the liquid pressed out from the grated potatoes; at first, it is colourless, but gradually becomes darker. The substance, not yet accurately studied, which effects this change of colour, is designated by the general term *colouring matter;* it is soluble in water, as is evident from the last-mentioned property.

Experiment.—Mix twenty drops of sulphuric acid with three ounces of water, and pour this acid water upon a potato cut in thin slices; after standing twenty-four hours the slices are to be taken out, and washed with water till they have no longer an acid taste, and then dried. During this process the potatoes lose their juices, and also their albumen and colouring matter, and, after drying, form a solid, mealy, white, and tasteless substance, which swells up and becomes soft when boiling water is poured upon it. Potatoes dried without this treatment become grey and horn-like, and acquire an unpleasant smell.

452. *Peas.*—*Experiment.*—Pour a handful of peas into a capacious vessel containing water, and let it stand for some days in a warm room; a great part of the water is absorbed by the peas, causing them to swell up, and finally to become so soft that they can easily be mashed between the fingers. When in this state, bruise them in a mortar, and add sufficient water to form with them a thin paste, which may be squeezed out by means of a linen cloth. Here, also, we obtain, as from potatoes,—1, a *fibrous substance,* which remains on the cloth; 2, starch, which is deposited, after standing, from the turbid liquid; 3, *vegetable albumen,* when the decanted liquid is heated to boiling.

Experiment.—When you have separated the vegetable albumen, by boiling and filtering, from the above-mentioned liquid, add to the latter a few drops of any acid; a flaky white body will again be deposited; this is called *vegetable caseine* (cheesy matter), on account of its great similarity to the cheese contained in milk (animal caseine) in its constitution and also in its properties. Vegetable caseine, like vegetable albumen, contains *nitrogen;* but it is distinguished from the latter by this, namely, that it is not *coagulated* by boiling, though it is *by acids.* It occurs in the juice of many plants, but it is most abundant in the seeds of leguminous plants; potatoes, likewise, contain small quantities of it.

453. *Wheat Flour.—Experiment.*—Moisten a handful of wheat-flour with sufficient water to form a stiff paste when triturated in a mortar; enclose it in a piece of thick linen, and knead it frequently, adding water as long as the liquid which runs through continues to have a milky appearance. After standing some time, a white powder will settle from the turbid water; this is *wheat starch.*

Starch is one of the principal constituents of flour, as, indeed, of all sorts of meal; the second constituent remains behind in the cloth, mixed with vegetable fibre, and is a viscous, tough, grey substance, which has received the name *gluten* (vegetable fibrine). The gluten only swells up in water, without being completely dissolved; in its constitution it corresponds exactly with albumen, and, like this, contains *nitrogen.*

When the water decanted from the starch is boiled, it becomes turbid, and, when partially evaporated, yields a flocculent precipitate; thus, wheat-flour contains also some *vegetable albumen.*

454. If the results of these experiments are grouped together, we shall find that there are always present in potatoes and peas, and also in wheat-flour, the two non-nitrogenous substances, vegetable tissue and starch, and also one or several of the nitrogenous compounds, vegetable albumen, caseine, and gluten.

Non-Nitrogenous Substances.

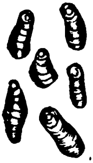
In potatoes: vegetable tissue, starch;
In peas: vegetable tissue, starch;
In wheat: vegetable tissue, starch.

Nitrogenous Substances.

In potatoes: vegetable albumen, caseine (little);
In peas: vegetable albumen, caseine (much);
In wheat: vegetable albumen, gluten (much).

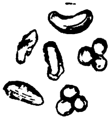
The three substances above named, containing nitrogen and sulphur, have the general name of *albuminous compounds;* hitherto they have been called *proteine-compounds.* Small quantities of one or more of them occur in the sap of every plant.

Fig. 181.



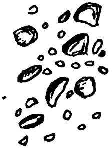
455. *Potato starch* exhibits, under the microscope, the form of egg-shaped grains, consisting of many scales overlapping each other; it glistens in the sun, is hard to the touch, and has always more of a pulverulent than of a concrete character.

Fig. 182.



In the *starch of peas* many of the grains are concave longitudinally, while others seem to be formed by the growing together of several globules.

Fig. 183.



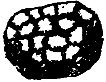
Wheat starch consists of dull, flattened, lenticular grains, which, when moist, readily adhere to each other, on which account the wheat starch of commerce always comes in loose lumps. When ground, it is known under the name of *hair-powder, &c.*

Arrowroot is a starchy meal used in medicine, which is prepared in the East and West Indies from the roots of some marsh plants.

456. *Experiment.*—If some starch is placed in a ladle, and gently heated with constant agitation till dried up, hard, horny granules are obtained, which swell when boiling water is poured on them, and become gelatinous and translucent; these granules are called *sago.* Genuine sago comes from India, where it is prepared from the starch which is extracted from the pith of various palm-trees.

We find also starch granules swollen by water in boiled potatoes. One pound of crude potatoes contains about three-quarters of a pound of watery juice, and from two to two and a half ounces of starch; at the heat of boiling water or steam, this juice is absorbed by the starch, so that the swollen grains fill up the cells, which thereby acquire a round shape. The reticulated appearance in the annexed magnified cell arises from the coagulated albumen of the juice, which fills up the interstices between the separate granules. All our baked food contains starch as its principal ingredient, and owes to it its friable and light character.

Fig. 184.



457. *Experiment.*—Heat in a vessel half a drachm of starch, with an ounce or an ounce and a half of water, constantly stirring it till it boils; the mixture first becomes slimy, and finally as thick as a jelly. The grains of starch absorb water, and swell up, so that the single membranes break open. This swollen starch is well known for its adhesive properties, and is variously employed as a means of thickening printing colours. When linen and other woven fabrics are passed through a thin paste of starch, they acquire, after drying, a degree of stiffness, and by ironing or strong rubbing and pressing a bright gloss (starching). The swelling of many of our most common articles of food, such as rice, groats, barley, beans, peas, lentils, &c., when boiled with water, is now readily explained by their containing a large quantity of starch.

Experiment.—If you let some starch paste remain for a length of time in a warm place, it gradually becomes thin and sour; it thus passes into a peculiar acid, which has received the name of *lactic acid.* The same acid is produced when milk becomes sour, and it imparts to curdled milk and to buttermilk their well-known sour taste.

Experiment.—Dilute some starch paste with a large proportion of water, and add to it a few drops of tincture of iodine (§ 155); an intensely deep *blue* liquid (*iodide of starch*) is produced. The same colour may be perceived by dropping some tincture of iodine upon flour, potatoes, carrots, &c. We have in iodine an extremely delicate test for starch.

There is a peculiar kind of starch called *inuline*, which occurs in the roots of the elecampane and the dandelion, and in the bulbs of the dahlia; this is coloured yellow by the tincture of iodine.

Another variety of starch, which is coloured brown by the tincture of iodine, is found particularly in Iceland moss, and is called *lichenine*.

Change of Starch into Gum and Sugar.

458. *Starch Gum.—Experiment.*—If starch is heated in a ladle over a gentle alcohol flame, and during the heating (roasting) is constantly stirred to prevent its burning and baking on the bottom of the ladle, it acquires after a while a yellow, and finally a brownish-yellow colour, and then possesses the new property of dissolving, both in cold and in hot water, into a mucilaginous liquid. (Common starch is entirely insoluble in cold water, and only swells up in hot water.) Starch thus transformed is called *roasted starch, starch gum*, or *British gum*. It is well adapted for the thickening of colours and mordants in calico-printing, and therefore is now often made on an extensive scale, usually by roasting starch in large coffee-roasters.

Experiment.—Mix thoroughly, in a small dish, half an ounce of starch with one drachm of water and four drops of nitric acid; let the mixture dry in the air, and then place it on the plate of a heated oven, which is just hot enough to hiss feebly when touched with the moistened finger. After some hours, all the nitric acid will be expelled, and the starch will dissolve almost entirely in cold water, and completely in hot water. *Starch gum* thus made is white, or has only a slight yellowish tinge.

Experiment.—Make a paste of potato starch by boiling starch with water, and, while still hot, add to it, in a saucer, some drops of sulphuric acid, with constant stirring. That this acid effects a change is evident, for the viscid mass very soon becomes a thin liquid. Now place the saucer on a jar, in which some water is simmering (steam-bath), and let it remain over the hot steam (the contents of the saucer not being heated quite to the boiling point) until the liquid has become semi-transparent. When this is the case, add prepared chalk by small portions at a time to the liquid, until it ceases to give an acid reaction, and after having filtered it from the gypsum, leave it to evaporate in a warm place. The dry residue has an amorphous, vitreous appearance, an insipid taste, and dis-

Fig. 185.

solves in water, forming a transparent viscid fluid; it is not soluble in alcohol. Vegetable substances with such properties are usually called *gums;* the gum obtained from starch has received the special name of *dextrine.*

459. *Starch-Sugar.—Experiment.*—Repeat the former experiment, with the following deviation. Bring to brisk boiling two ounces and a half of water, to which twenty drops of sulphuric acid have been added, and then add one ounce of starch mixed with a little water, forming a paste, but only in small quantities at once, that the boiling may not be interrupted. When all the starch is stirred in, let the mixture boil for some minutes, then neutralise the acid with chalk, and evaporate the filtered liquid to the consistency of a thick syrup. It possesses a very sweet taste, and consists of a solution of sugar in water. The *starch-syrup* thus made, as well as the white, solid *starch-sugar*, easily prepared from it, are now both articles of commerce.

Starch, as shown by these experiments, is converted by sulphuric acid, on moderate heating, into gum; on stronger heating, into sugar. In the latter case, also, dextrine is first formed, but this soon passes over into sugar. Accordingly, sulphuric acid exerts two different actions. By the first action, the starch becomes *gum* (dextrine). By the second action, the dextrine becomes *sugar.*

It has not yet been explained how this effect is produced. Starch, starch-gum, and starch-sugar have each the same constitution (isomeric), so that their difference undoubtedly depends upon a different arrangement of the atoms of carbon, hydrogen, and oxygen contained in them, and it is undoubtedly the sulphuric acid which effects this change in the position of the atoms. No portion of the sulphuric acid has been decomposed, neither has any of it combined with the organic substance; for we find again, in the sulphate of lime formed, exactly the same quantity of sulphuric acid that had been originally employed. Accordingly, in this case it exerts an action quite different from the usual action; it is an action like that of spongy platinum, which can excite a chemical activity in another substance, without itself undergoing any change. This peculiar mode of action of sulphuric acid and of platinum is often designated by the name of "action of *presence*" (contact), or action by *catalysis* (power of conversion).

460. *Malt and Diastase.—Experiment.*—Pour two ounces of lukewarm water upon a quarter of an ounce of coarsely pulverised barley-malt; let the mixture remain some hours near a fire or stove, or in the sun, and then strain it through a linen cloth; there is found in the filtrate a substance not yet well known, called *diastase*, by means of which the starch may be converted into *gum* and *sugar* in the same way as by sulphuric acid.

Experiment.—Rub a quarter part of the diastase with some hot starch paste, made of a quarter of an ounce of potato starch and two ounces of water; heat the mixture moderately, but not above 149° F. (65° C.), until the paste is formed into a thin, transparent liquid. Now boil this liquid for some time at a stronger heat, strain through a cloth, and let it evaporate in a warm place. The mass remaining behind is like that obtained at § 458, and consists of *dextrine*, or starch-gum.

Experiment.—Treat the other three-quarters of the diastase in the same way, but prolong the heating for several hours, which may be most conveniently done on the hearth of a stove or fireplace, applying to the liquid a heat not above 158° F. (70° C.) or 167° F. (75° C.) Here also dextrine is the first product formed; but this is soon converted on further boiling into starch-sugar, as may easily be perceived by its taste. By evaporation, syrup of starch is obtained, as in § 459.

461. The remarkable change which malt causes in starch is to be ascribed to the *diastase* contained in the malt. This substance obviously acts in a very similar manner to sulphuric acid, but its mode of action is as yet likewise unknown. At 212° F. (100° C.), consequently, on boiling the liquid, the effect of the malt (diastase) is destroyed. The process of forming sugar by means of the diastase of malt is of great importance to the brewer and distiller, as in the manufacture of beer from barley or wheat, or spirit from rye and potatoes, the starch of these substances must always be previously converted into sugar, before fermentation and the consequent formation of alcohol can take place. In both cases it is the

diastase of the malt, which is indispensable in brewing and in the distillation of spirit, that effects this change in the so-called *mashing process*.

462. The taste of *malt* is sweet and mucilaginous, because the conversion of the starch into dextrine and sugar commences during germination, the further progress of which is arrested in this case by drying. If the germinated barley is allowed to continue growing, as it does in the open fields, all the starch gradually vanishes from the grain, and passes, in the form of dextrine and sugar, into the juice of the young plant, as is obvious from the sweet taste of the latter, and from its mucilaginous feeling when rubbed between the fingers.

A similar metamorphosis is also clearly to be perceived in potatoes. The quantity of starch contained in one hundred pounds of the same kind of potatoes has been found to be, in August, 10 pounds; in September, 14; in October, 15; in November, 16; in December, 17; in January, 17; in February 16; in March, 15; in April, 13; in May, 10. Accordingly, the quantity of starch in potatoes increases during the autumn, remains stationary during the winter, and in the spring, after the germinating principle is excited, it diminishes. It is a well-known fact, that on germination potatoes become soft, mucilaginous, and afterwards sweet; the dextrine forming from the starch renders them mucilaginous, and the sugar forming from the dextrine renders them sweet. This process of transformation advances still further in the earth, the potatoes becoming constantly softer and more watery, and when the starch is completely consumed in the growth of the young plant, the process of decay commences, and its products, carbonic acid, water, and ammonia, may be regarded as food for the somewhat older plant.

463. Unripe apples and pears are coloured blue by tincture of iodine; consequently they contain starch. When completely ripe, they cease to give this reaction; therefore starch has disappeared on ripening, as appears by the taste of the fruits; they are sweet, and we must therefore presume that here also a transformation of the starch into dextrine and sugar has taken place. It appears, also, that frost is capable of exerting a similar influence upon these vegetable substances, which are rich in starch; it is well enough known, that frozen potatoes, apples, medlars, &c., have a sweet taste after being thawed.

III. GUM AND VEGETABLE MUCUS.

464. It has already been explained, when speaking of dextrine, what kind of vegetable matter is called *gum*, and likewise that it is an intermediate substance between starch and sugar. Dextrine is one of the most widely diffused substances in the vegetable kingdom, since we find it in greater or less quantities in the juice of every plant.

But there exist in many plants certain sorts of gum, and sometimes in such abundance, that they exude from the bark as a viscid liquid, and harden upon it in transparent globular masses, such as we see on our peach and cherry trees. The name *resin*, by which these dried vegetable juices are frequently designated, is erroneous, because by resins are meant those vegetable juices which do not dissolve nor soften in water, but are soluble in alcohol. The action of gum is different; this is insoluble in alcohol, but is softened and dissolved by water.

465. *Gum Arabic.*—The best known of these peculiar sorts of gum is gum Arabic, which exudes spontaneously from several species of acacia in Africa. The finer sorts of it are white; the more common kinds have a yellow or brown colour. When well dried, it is so hard and brittle that it may be reduced to a powder by pounding.

Experiment.—Pour two drachms of cold water on one drachm of gum Arabic, and occasionally stir the mixture; the gum will, after a few days, entirely *dissolve* in the water, forming a viscid transparent *mucilage*, which may be diluted at pleasure with more water. This mucilage has great adhesiveness, for which reason it is often used, instead of paste or glue, for joining together paper, &c., or for converting a pulverulent substance into a coherent mass (crayons, pastilles, &c.); it has, moreover, a thick consistency, and hence is variously employed in calico-printing as a thickening material for colours and mordants, and in finishing and dressing operations. A variety of gum obtained from the shores of the Senegal, whence it has been called *gum Senegal*, is peculiarly well adapted for the latter purpose, as it yields a thicker mucilage than the common gum Arabic.

Experiment.—Pour some drops of mucilage of gum Arabic into alcohol; they will not mix with each other, as the gum is insoluble in alcohol. If the mucilage is previously mixed with water, forming a thin clear liquid, and is then added to the alcohol, a turbidness ensues, and afterwards a flaky precipitate will subside; accordingly, alcohol may be used for removing gum from those liquids which contain it.

In a chemical sense, only those sorts of gum are designated by the name of *gum* which dissolve completely in cold water, and thus form a clear, transparent liquid.

466. *Gum tragacanth* is also a vegetable exudation, well known as a stiffening material, and as forming with water an adhesive paste; it exudes from a shrub which grows in Greece and Turkey, and it occurs in commerce in the form of white, tortuous filaments, or bands.

Experiment.—Let a piece of tragacanth remain for some days in cold water; it will soften and swell into a stiff, viscid jelly; a single drachm of it is sufficient to convert one pound of water into a thick mucilage. The tragacanth does not dissolve, but, like starch, only *swells up;* if the mucilage is boiled, the mass becomes more uniform, but a complete solution is not effected.

This kind of gum has been called *vegetable mucus* (bassorine), to distinguish it from the former; it occurs also in many other plants, as, for instance, in the leaves of the mallows and the coltsfoot, in the roots of the althea and salep, in flax and quince seeds, and in carrageen, &c. This mucilage abounds in the cores of the quince, for it surrounds the seeds as a whitish, transparent substance; it must obviously be very plentiful, since one drachm of quince-cores is sufficient to convert half a pound of water into a thick mucilage.

467. *Experiment.*—If you pour a large quantity of water upon some of the *gum of cherry or plum* trees, part of the gum will be dissolved after some time, but a part will remain undissolved as a swollen mass (vegetable mucus, cerasine). These two vegetable exudations must accordingly be regarded as mixtures of gum and vegetable mucus.

468. *Pectine.*—The juices of many fruits and roots, for instance, currants, gooseberries, cherries, apples, carrots, &c., contain a peculiar kind of mucus, which communicates to the juice the property, especially when previously boiled with sugar, of hardening into a gelatinous mass after cooling.

This mucus, to which the solidification of the juice is to be ascribed, has received the special name of *pectine* (vegetable jelly).

IV. SUGAR (SACCHARUM).

469. *Sugar of Starch.*—The manner of converting starch into sugar has already been described under the head of Starch. This sugar may be prepared in two ways; either by boiling with diluted sulphuric acid (syrup of starch), or by digesting the starch with malt or diastase (malt syrup). Both of these syrups may be regarded as concentrated solutions of sugar in water. If a very concentrated syrup of starch is allowed to remain standing for some time, a granular sediment separates from it, while a part of the solution of sugar remains fluid and ropy. The solid sugar thus obtained, which consists of fine granules, is called *starch sugar*, and the liquid portion, which, even on being evaporated to dryness, always again attracts moisture and deliquesces, is called *liquid sugar*.

Honey bears a strong resemblance to starch-sugar. If it is kept for some time after being melted, the mass, at first homogeneous, likewise separates into two parts, into a granular solid residue, and into a syrupy liquid. The former consists of starch-sugar, the latter of liquid sugar.

This species of sugar (starch-sugar) is formed also in many vegetables, and is especially abundant in fruits; as, for example, in plums, cherries, pears, figs, grapes, &c. The white coating of prunes, and the white, sweet grains in raisins, consist of it. On account of this origin, sugar of starch is also called *grape-sugar*.

If you taste a dried granule of sugar from a raisin, and then a little common sugar, you will at once perceive that the former is much *less sweet* than the latter; one ounce of common sugar has the same sweetening power as two ounces and a half of grape-sugar. The solubility of these two varieties of sugar in water is likewise very different, grape-sugar dissolving in it much less readily and more slowly than common sugar. While one ounce of cold water can dissolve three ounces of common sugar, it is able to take up only two-thirds of an ounce of grape-sugar; the solution of sugar (syrup) prepared from the former is, accordingly, of a much stronger and more tenacious consistency than that prepared from grape-sugar.

470. *Cane-Sugar.*—Our common sugar is different from those kinds of sugar just described; it is either prepared in the tropical regions, from the juice of the sugar-cane (cane-sugar), or in France and Germany, from the juice of the beet (beet-root sugar).

The operations whereby this sugar is obtained on a large scale are the following:

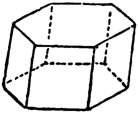
1. *Expressing* the juice from the sugar-cane or the rasped pulp of the beet, either by strongly squeezing, or by hydrostatic pressure.

2. *Boiling down* the juice with the addition of lime, by which several foreign substances are precipitated, until it acquires the consistency of a thick syrup; on cooling, the crude sugar is deposited from it, in brownish-yellow crystalline grains (*raw sugar*, or *Muscovado sugar*). The liquid sugar which does not crystallise is allowed to drain off, and forms the well-known *brown syrup* (molasses).

3. *Refining* the raw sugar—that is, the removal of the brown syrup still adhering to it. This is done—*a*), by redissolving the raw sugar in a little water; *b*), by filtering the brown solution through coarsely-ground animal charcoal, which retains the colouring matter; *c*), by evaporating the clarified solution in vacuum pans. The concentrated syrup is then allowed to cool in moulds of a conical shape, stirring it frequently to disturb the crystallisation. A solid mass, consisting of small fragmentary crystals, the common *loaf-sugar*, is obtained, from which the remaining liquid sugar is removed by letting a concentrated solution of crystallisable sugar gradually percolate through (*liquoring*). The thoroughly purified and glistening white sugar is called refined loaf-sugar; that which is not so completely clarified, and has a yellowish tinge, is the common loaf-sugar.

Experiment.—Dissolve half an ounce of sugar in a quarter of an ounce of hot water; the viscous solution is called *white* (*simple*) *syrup*. If this solution is put in a cup, and set aside in a warm place, and evaporated slowly, the sugar will sepa-

Fig. 186.



rate from it, crystallising in oblique six-sided prisms. In a similar manner white *sugar-candy* is prepared on a large scale from refined sugar, brown candy from raw sugar. As the crystals deposit more readily on substances having a rough than on those having a smooth surface, fine threads or pieces of wood are stretched across the vessels containing the syrup, and they soon become coated with crystals.

471. Cane-sugar, as already stated, has a much sweeter taste than grape-sugar; therefore, when used as a sweetening agent, it possesses a far greater value than the latter. The white sugar now occurring in the market in Germany is frequently found to be composed partly or entirely of starch-sugar.

Experiment.—Put into a test-tube a piece of cane-sugar, and into another some granules of grape-sugar taken from a raisin, and pour over them strong sulphuric acid; the cane-sugar becomes black by gentle heating (it is charred), but not so the starch-sugar. An opposite reaction takes place when the two sorts of sugar are heated with a solution of potassa; the grape-sugar, but not the cane-sugar, assumes a dark colour.

Experiment.—These two sorts of sugar may be more accurately distinguished from each other by the copper test. First add to the solutions of sugar some drops of a solution of blue vitriol, then some drops of solution of potassa, and place both vessels in hot water; the liquid containing the grape-sugar assumes in a few minutes a reddish-yellow colour, while that containing the cane-sugar remains blue. The grape-sugar is able to abstract from the oxide of copper half of its oxygen, whereby reddish-yellow suboxide of copper is formed. (§ 354.) Cane-sugar is also able to effect this change, but not till after boiling, or after standing several days. The sugar is converted by the oxygen taken up into an entirely new substance, called formic acid. Grape-sugar may be distinctly recognised by this test, even in an extremely diluted solution.

472. *Liquid* or *mucic Sugar.*—By this very indefinite name are commonly designated all those kinds of sugar which do

not yield on evaporation a solid crystalline or granular, but a vitreous amorphous mass, which on exposure to the air again attracts water, and deliquesces. This kind of sugar is commonly called syrup and molasses.

473. *Sugar of milk* is that particular kind of sugar which occurs in milk, and imparts to it its agreeable sweetish taste. It is obtained in hard, white, crystalline masses, by evaporating the sweet whey. Sugar of milk is much less sweet to the taste than grape-sugar, and requires six parts of cold water for its solution. It is well known that milk becomes sour by standing for some days; this is owing to the sugar of milk being gradually converted into a peculiar acid, called lactic acid.

474. *Mannite* is a substance resembling sugar, constituting the principal part of manna (the concrete sweet juice of some species of the ash, growing principally in Italy).

CHANGES OF SUGAR.

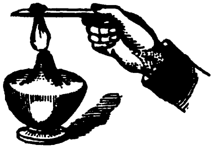
475. *a.*) *Change by Heat.—Experiment.*—Boil in a dish half an ounce of sugar with one drachm of water, until the viscous solution begins to assume a yellowish tinge; then pour it upon a plate previously smeared with a little olive-oil. The transparent brittle mass is melted sugar in an *amorphous* state (barley-sugar or *bonbons*). The sugar is first dissolved by the water; on boiling, the water is again evaporated, and the sugar passes gradually from the dissolved to the melted state. The yellowish colour indicates that all the water has passed off, and that the sugar is on the point of becoming burnt.

If the transparent sugar is kept for some weeks, it becomes opaque and crystalline, when it can easily be broken up and finely comminuted. There is a scientific interest in this, as it clearly affords another illustration (§ 280) of the fact, that, even in a solid state, the smallest particles of sugar (its atoms) can change their situation with respect to each other.

Experiment.—Repeat the former experiment, but without stopping the heating on the appearance of the yellow colour; the sugar will grow darker, until it finally attains a brownish-black colour, and will exhale, at the same time, a peculiar empyreumatic odour. On cooling, it is obtained as a hard, almost black mass, which soon deliquesces in the air, forming a dark syrup, and is called ***burnt sugar***, or ***caramel***. A couple of drops of it impart to a large vessel filled with water the appearance of Jamaica rum. On account of its strong colouring properties, burnt sugar is much used for imparting to liquors—vinegar, alcohol, &c.—a yellow or brown colour.

Experiment.—When exposed to a still stronger heat, the sugar becomes charred, and finally burns like wood, as may easily be seen by holding a piece of it on platinum foil over an alcohol flame. The flame indicates also that inflammable gases are evolved. Pure sugar leaves *no* residue. If it contains lime, white ashes remain behind upon the foil, which do not volatilise even at the strongest heat.

Fig. 187.



476. *b.) Change by Acids.—Experiment.*—If you add a few drops of lemon-juice, or a little tartaric acid, to a thick, boiling solution of sugar, it immediately becomes a thin liquid, which does not crystallise on evaporation; thus is explained why the sweet juices of fruits, in which organic acids are always present, do not yield, on being boiled down, a solid sugar, but only a thick syrup. If you treat the solution of sugar as directed in the copper test (§ 471), you will find that it now contains grape-sugar; cane-sugar is therefore converted by boiling with organic acids into grape-sugar. This metamorphosis is produced also in various other ways, as by mere prolonged boiling of the solutions of sugar, by boiling them with diluted sulphuric acid, by fermentation, &c. If sugar is boiled for a long time with diluted sulphuric acid, it finally passes into a brown substance, resembling humus. When boiled with nitric or other acids, which yield oxygen, it oxidises first into saccharic acid, then into oxalic acid, and finally into carbonic acid and water.

Sugar, as though it were an acid, can combine in fixed proportions with oxide of lead, lime, and many other bases; but it thereby loses its sweet taste.

RETROSPECT OF THE VEGETABLE MATTERS HITHERTO CONSIDERED (VEGETABLE TISSUE, STARCH, GUM, MUCUS, AND SUGAR).

1. *Organic substances* are such chemical combinations as are formed in animals and vegetables during life (educts).

2. But we also designate by this term those chemical compounds which are formed from animal and vegetable matters, whether they are *transformed* with or without artificial assistance (products).

3. Organic matter undergoes decomposition with *remarkable facility*. We observe such changes,—

a.) In living animals and plants (germination, ripening, &c.,—respiration, digestion, &c.).

b.) In dead animals and vegetables (fermentation, putrefaction, decay, &c.).

c.) In the decay of animal and vegetable matter (charring, burning, &c.).

d.) In the treatment of organic substances with acids, bases, &c.

4. In all these changes, the form only of the organic body disappears; the elements of which they consist are unchangeable: they vanish from our sight only because they assume an aeriform shape.

5. We have not yet succeeded (with a few unimportant exceptions) in *preparing* and *imitating* the organic combinations by putting together their constituent parts; we are only able to *decompose* them, and to *convert* the elements into new bodies.

6. The four organogens, oxygen, hydrogen, carbon, and nitrogen, are the principal constituents (the elementary constituents) of all that lives and has ever lived. A few inorganic substances only are added to them, as sulphur, phosphorus, potassium, calcium, &c.

7. These four organogens have the power of combining in an *unlimited* manner with each other, and, indeed, not only with each other, but also with many inorganic substances; the number of the organic combinations is therefore almost infinite.

8. Thus, since the difference of organic matter cannot, as in inorganic substances, consist in the number of the constituents, so the cause of this difference must be sought for in the varied juxtaposition or *grouping* of these constituents (*compound radicals*).

9. *Vegetable tissue*, *starch*, *gum*, *mucus* and *sugar*, are among the most widely diffused of the groups of atoms (or proximate constituents) occuring in the vegetable kingdom. They are present in all plants.

10. They have neither acid nor basic properties, and are therefore called *indifferent* vegetable substances.

11. There is a very great similarity in their constitution; namely, they consist of only three elements, *carbon*, *hydrogen*, and *oxygen* (they are non-nitrogenous); and, moreover, they contain oxygen and hydrogen always *in the same proportions as in water*, namely, in equal atoms.

12. These four proximate constituents of the vegetable kingdom form a *principal ingredient of all our vegetable food;* they play, accordingly, a very important part in the process of animal life.

V. ALBUMINOUS SUBSTANCES (NITROGENOUS AND SULPHURISED SUBSTANCES).

ALBUMEN, CASEINE, AND GLUTEN.

477. UNDER the head of Vegetable Tissue, when speaking of the preparation of starch, it has already been shown what is to be understood by vegetable albumen, caseine, and gluten, and that all plants contain in their juice, one or more of these nitrogenous substances.

Vegetable albumen is soluble in water, but is rendered insoluble by *boiling* (it coagulates). It is found particularly abundant in culinary plants and in oily seeds, as in almonds, rape-seed, linseed, poppy-seed, &c.

Vegetable caseine is likewise soluble in water, yet it does not coagulate by heat, though it does by adding an *acid* to a solution of it. The leguminous plants, such as peas, beans, lentils, &c., are very rich in it.

Gluten (vegetable fibrine) is insoluble in water, and forms an essential part of wheat.

Experiment.—Add to one drachm of bruised peas half a drachm of caustic potassa and one ounce of water, and boil the mixture till a drop of the liquid causes a brown spot on lead-paper (paper which has been moistened with a solution of sugar of lead). The dark colour produced on the lead-paper is owing to the formation of sulphuret of lead; it indicates that *sulphur* from the peas has been rendered soluble by the potassa. By now adding a few drops of sulphuric or muriatic acid to the liquid, the presence of the sulphur also makes itself known by the smell, since sulphuretted hydrogen gas is evolved. (§ 213.) Vegetable albumen and gluten, when thus treated, give rise to the same phenomena. The tarnishing of silver spoons on remaining for some time in boiled peas, &c., is now simply explained, as sulphuret of silver has been formed on the surface. Vegetable albumen (likewise animal albumen) contains, besides sulphur, a small quantity of phosphorus.

The albuminous substances have also been called *proteine* substances, because it was assumed that a common fundamental body (an organic radical) was contained in them, to which the name *proteine* was given.

478. It has been ascertained by careful experiments, that the chief proximate constituents of animal matter have the same constitution as the albuminous substances of the vegetable kingdom, and this has led to the conclusion, that the component parts of the bodies of those animals whose food consists entirely of vegetables, are derived from these albuminous substances. This conclusion is most fully confirmed by the constitution of the blood, the component parts of which are albuminous matter (albumen and animal fibrine). Now, as the blood is the medium of nourishment, the blood being first formed from the food, and afterwards all the other parts of the animal body from the blood, so we may fairly infer that from the albumen, caseine, and gluten which we receive in the form of bread, peas, &c., the albuminous substances of the blood are formed, and from these the other parts of the body. For this reason, articles of food are esteemed nutritive nearly in proportion to the amount of nitrogen they contain.

CHANGE OF ALBUMINOUS SUBSTANCES BY DECAY AND PUTREFACTION.

479. *Formation of Ammonia.*—*Experiment.*—Put some gluten, some coarse flour, or some peas, into a flask, pour in some water, and connect the flask by means of a glass tube with a second flask, filled about an inch deep with water, and let them remain in a moderately warm place. Insert, also, between the cork and the neck of the first flask, a strip of lead-paper, in such a manner that part of it shall hang down into the flask. The following changes will be observed to

take place, more rapidly at a warm, more slowly at a cold temperature:

a.) Bubbles of gas escape from the glass tube into the second flask; they consist of *carbonic acid* (and some hydrogen), as may be seen by the turbidness which follows on the addition of lime-water.

b.) The lead-paper is coloured dark, a sign of *sulphuretted hydrogen* being generated.

c.) A pungent smell of ammonia is evolved from the liquid standing over the gluten when it is heated with lime or potassa; consequently *ammonia* has also been formed.

If we compare this process of decomposition with that which takes place on the putrefaction of non-nitrogenous substances (§ 445), we shall observe the following principal difference in the result:—*On the putrefaction of albuminous substances, their nitrogen and sulphur (and phosphorus) combine with hydrogen, forming ammonia and sulphuretted hydrogen (and phosphuretted hydrogen).* These aeriform substances are the chief cause of the very disagreeable odour which is given off during the decay or putrefaction of nitrogenous substances,—for instance, animal substances. During the further progress of this decomposition, there is formed also, as with ligneous fibre, a brown substance resembling humus.

However disgusting may be the products of putrefaction and decay, they nevertheless contain within themselves the germ of the most beautiful compounds; the most beautiful plants arise from such products of decay. Indeed, the most disagreeably smelling decaying nitrogenous substances are the most powerful means of rendering our fields and gardens fertile (the best manures).

480. *Formation of Nitre.—Experiment.*—Mix some linseed meal with wood-ashes, sand, and lime, and let this mixture remain exposed to the air for several months in the summer season, frequently moistening it with water, and stirring it. If the mixture is then treated with hot water, and the solution evaporated, prismatic crystals will be formed from the latter on cooling, which will detonate smartly when thrown upon glowing coals; they consist of *nitre.* (§ 207.)

Here, also, ammonia is in the first place formed from the nitrogen of the vegetable albumen, present in great abundance in the linseed meal; but it is induced by the predisposing influence of the strong base to undergo still further putrefaction, that is, to attract oxygen from the air, whereby water is formed from its hydrogen, and nitric acid from its nitrogen, the latter of which combines with the potassa and lime.

$$\begin{array}{rcll} \text{From ammonia} & = & N & H_3 \\ \text{and oxygen} & = & O_5 & O_3 \\ \hline \text{are formed nitric acid and water} & = & N\,O_5 + & 3\,H\,O. \end{array}$$

In a similar manner nitre is often generated in the soil, whence it passes into the sap of plants; thus it is known that beets and tobacco growing upon very strongly manured soil, and also those rank plants growing on manure heaps, such as henbane, thorn-apples, &c., are frequently so rich in nitre, that when dried they emit sparks when burnt on charcoal.

481. The extraordinary facility with which albuminous substances undergo *decomposition*, when they are exposed to the air in the moist state, is explained very simply by the fact that they contain five, indeed, six elements, and always several atoms of each, as component parts. (§§ 425, 429.) If during their decomposition they come in contact with non-nitrogenous substances, these also are induced to enter into decomposition—they are, as it were, infected. Of special importance, in regard to this point, is the important change which *sugar* experiences when it is brought in contact with albuminous substances in a state of decomposition. This metamorphosis, known under the name of spirituous fermentation, will be more particularly considered in the following pages.

RETROSPECT OF THE ALBUMINOUS SUBSTANCES (ALBUMEN, CASEINE, GLUTEN).

1. The albuminous substances are characterised by containing, not only carbon, oxygen, and hydrogen, but also *nitrogen* and *sulphur*.

2. On account of this complex nature, *they are decomposed with the greatest ease* (fermentation, putrefaction, decay).

3. If while they are decomposing they come in contact with other organic substances, they cause these also to enter into fermentation, decay, putrefaction, &c.

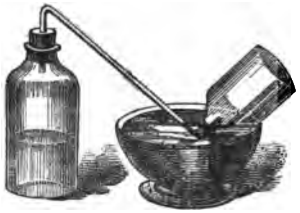
4. All vegetables contain, though not always in great quantity, one of these substances; from this universal diffusion, we infer that it has an important office to discharge;

5. Which office consists undoubtedly in this, that by means of it the growth and nourishment of plants may be brought about.

VI. CONVERSION OF SUGAR INTO ALCOHOL (VINOUS FERMENTATION).

482. *Experiment.*—Half an ounce of honey is dissolved in four ounces of water, and some of the gluten or caseine from experiment § 479, in a state of decomposition, is added to it; the liquid is then put in a moderately warm place, from 64° F. (18° C.) to 75° F. (24° C.), when it soon enters into fermentation, with the evolution of a large quantity of gas. If you perform the experiment in a bottle furnished with a bent glass tube, one end of which is passed under a second bottle, filled with water, which is inverted over the pneumatic trough, the gas may easily be collected; it consists of carbonic acid. If the liquid still retains a sweet taste after the evolution of the gas has ceased, then add another portion of the gluten to it, whereby the fermentation is again renewed. Finally, all the saccharine taste will have disappeared, and the liquid will have acquired a spirituous flavour. The fermented liquor is called *mead;* instead of sugar it contains *alcohol,* and this is the cause of its intoxicating effect. A portion of the gluten is found at the bottom of the vessel, converted into a brownish residue.

Fig. 188.



All albuminous matter in a state of decomposition, as, for instance, old cheese, putrefying flesh, blood, &c., acts like putrefying gluten; but the substance which possesses this fermenting power in the highest degree is the altered gluten of barley, obtained in great quantity as a secondary product in the brewing of beer (surface yeast, or brewers' yeast). All substances which are able to excite fermentation in solutions of sugar are designated by the term *ferments.* Surface yeast (§ 488) is accordingly the most powerful ferment.

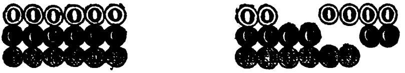
Experiment.—Repeat the former experiment, adding, instead of the gluten, a teaspoonful of yeast to the honey-water; the process of fermentation will now proceed much more rapidly and regularly.

483. The change which the sugar experiences during this process may be rendered very intelligible by comparing together the formulas of sugar, alcohol, and carbonic acid.

1 atom of honey or grape-sugar consists of $C_6\ O_6\ H_6$;
from this are formed 1 atom of alcohol $= C_4\ O_2\ H_6$,
and 2 atoms of carbonic acid $= C_2\ O_4 = 2\ C\ O_2$.

Alcohol and carbonic acid, added together, yield again the constituents of sugar. *Thus sugar is resolved by fermentation into alcohol and carbonic acid.*

Fig. 189.



Grape sugar. Alcohol. Carbonic acid.

Both substances did not previously exist in the sugar, but they are new products of a peculiar decomposition of the sugar,—peculiar for this reason, that they are exclusively made up of the elements of the sugar, without anything being either subtracted from it or added to it. The ferment acts also in the same peculiar manner; it induces a decomposition of the sugar, yet without combining with the sugar, taking anything from it, or giving anything to it. Its mode of operation is analogous to that of sulphuric acid, when the latter converts starch into sugar. (§ 459.) The action of the ferment, however, differs from that of sulphuric acid just alluded to, since the ferment itself does not remain unchanged, but is also decomposed during the fermentation. Accordingly, two sorts of changes are going on by the side of each other in the fermenting liquids:—1.) that of the nitrogenous ferment; 2.) that of the non-nitrogenous sugar. The ferment always commences the change, which is continued in the sugar, as if the latter were infected. The process is very similar to what occurs in the case of a fresh apple, which begins to rot on coming in contact with one already in the act of rotting.

Experiment.—Instead of honey, take a solution of white sugar, and add some yeast to it; in this case the fermentation will not take place so soon, since the cane-sugar must pass into grape-sugar before its decomposition into alcohol and carbonic acid can commence. This transition takes place simply by the addition of one atom of water; for if one atom of water is added to the cane-sugar, $= C_6 H_5 O_5$ there is formed $C_6 H_6 O_6$, or grape-sugar.

WINE.

484. All *sweet vegetable juices* pass *spontaneously* into fermentation without the necessity of adding to them a ferment, because they always contain sugar and one of the albuminous substances, as albumen, caseine, or gluten.

Experiment.—Submit freshly expressed beet-juice to a temperature of about 68° F. (20° C.) or 77° F. (25° C.); the juice will soon effervesce, deposit a sediment, and be converted into a spirituous liquid (beet-wine).

In the same manner currant and gooseberry wines are prepared from currants and gooseberries, cider from apples, the so-called cherry-water by fermenting and afterwards distilling cherry juice, rum by fermenting and afterwards distilling the juice of the sugar-cane, &c.

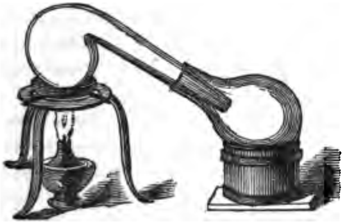
The most common of all the fermentations of this kind is the fermentation of grape-juice, wine being the result. In order to prepare *white* wine, the grapes are pressed, the juice (*must*) is poured into vats and allowed to remain in them in the cellar, where, as the temperature is tolerably low, the fermentation proceeds so slowly that it is not completed until after some months. The new wine is racked off from the lees, and poured into fresh vats; it still contains a small quantity of sugar and albuminous matter, which are both gradually converted, the former into alcohol and carbonic acid, the latter into lees (*secondary fermentation*). In the manufacture of *red wine*, the purple grapes are bruised, and then fermented, together with their skins and stalks; by which means a red colouring matter is extracted from the skins, and tannin from the stalks and seeds, the tannin imparting to this kind of wine its favourite astringent taste. *Sparkling* wine (Champagne) is made by allowing the secondary fermentation to take place in corked-up bottles, whereby the carbonic acid formed is retained in the wine.

485. The grapes growing in *northern countries*, for instance, in Germany, contain proportionably more albuminous matter and tartar than sugar, which accounts for the difference in the smell and taste of the wine made from them. The taste of these wines is not sweet, because the albuminous substances present are more than sufficient to decompose all the sugar; the odour (*the bouquet*) is peculiarly pleasant, because, the tartar being abundant, there is generated during the fermentation a volatile substance (*œnanthic ether*), which possesses a very agreeable odour.

It is different with the grapes of the more *southern countries*, as Greece, Spain, Portugal, &c. Here, in consequence of the higher temperature, the grapes are richer in sugar, but poorer in tartar and albuminous matter. In this case the latter substance is not sufficient to effect the decomposition of all the sugar during the fermentation, so that a part of the sugar remains undecomposed, and gives to the wine a sweet taste. Neither is any œnanthic ether generated, since the due quantity of tartar is wanting; consequently these wines possess no bouquet.

486. *Experiment.*—If some wine is put into a retort, and subjected to distillation at a moderate heat, at first the more volatile alcohol, together with the œnanthic ether, will pass over. A very agreeably smelling spirit is thus obtained, known in commerce under the name of *Cognac*, or *French brandy*. In the wine countries, the lees remaining after the wine is racked off are generally used for this purpose, since, in the swollen, pap-like state in which they settle in the vats, they retain mechanically a large quantity of wine.

Fig. 190.



BEER.

487. Next to wine, *beer* and *spirits* are the most important fermented liquors. The manufacture of them differs essentially from that of wine in this respect; that materials are

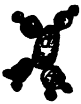
employed which contain no sugar already formed, but instead of it *starch*, such as barley, wheat, rye, potatoes, &c. Starch cannot, like sugar, be resolved directly into alcohol and carbonic acid; and, when employed in the manufacture of alcohol, it must previously be converted into sugar. This, in the present case, is always effected by the diastase of the barley-malt in the so-called mashing process of the brewers and distillers. (§ 461.)

Experiment.—Pour a mixture of an ounce and a half of cold water and two ounces of boiling water upon half an ounce of bruised malt, and set it aside for some hours in a warm place, where it will reach a temperature of about 149° F. (65° C.) or 167° F. (75° C.); a sweet liquid is thus obtained, composed, not only of dextrine and sugar, but containing also the gluten, thereby rendered soluble, which was present in the malt. The brewer calls this liquid the *wort.* Strain it with pressure through a cloth, and boil the liquid for some time, until it becomes clear and transparent; then let it cool to 86° F. (30° C.), and add to it a teaspoonful of yeast; it will soon begin to ferment, and after some days will clarify again; the clear, fermented liquor is *beer.* This is the mode of making the *Berlin white* or *pale beer*, which is not bitter. If during the boiling, some hops (female flowers of the hop-plant) are added to the wort, an aromatic bitter substance is dissolved from them *(lupulin)*, which not only imparts to the beer a pleasant and bitter taste, but also makes it keep better.

488. What is particularly remarkable in the above fermentation (*surface fermentation*) is the great quantity of yeast that separates. It proceeds from the gluten of the barley, which is dissolved during the mashing process, but in the course of the fermentation is again precipitated as insoluble yeast. This is called *surface yeast*, it being raised to the surface in consequence of the great evolution of carbonic acid, and if the casks are full, it is forced out of the bunghole; it is the best yeast, and the quantity obtained in the last experiment is sufficient to bring to complete fermentation the wort of a whole pound of malt. Its power of exciting fermentation is destroyed when it is rendered quite dry, or when it is boiled, or very finely triturated; and like-

wise by mixing antiseptic substances with it, as, for instance, alcohol, pyroligneous acid, sulphurous acid, volatile oils, &c. This yeast, when examined through the microscope, has exactly the form of simple vegetable cells (*a*); and their increase in the wort takes place in the same manner as in the most simple plants, new cells or buds developing themselves on each globule of the old yeast. These globules are hollow, filled with a nitrogenised liquid, to which is to be ascribed the power of the yeast to excite fermentation.

Fig. 191.



New beer contains, also, some sugar and gluten in solution; therefore, like wine, it undergoes, when kept, a second slight fermentation (*secondary fermentation*). If this is allowed to take place in well-stopped bottles, so that the carbonic acid cannot escape, a foaming beer (*bottled beer*) is obtained, in the same way as in the manufacture of sparkling Champagne.

But all the gluten is not separated, even by the second fermentation, and hence the upper fermenting (light) beer undergoes a still further change on being exposed to the air; it is the alcohol, however, which is now altered by the albuminous matter undergoing decomposition; it passes into vinegar, and the beer becomes acid.

489. *Experiment.*—Repeat the former experiment, but cool the wort below 50° F. (10° C.) before adding the yeast, and then let the liquid remain in a cool place; a very slow fermentation takes place, which will not be completed for several weeks, perhaps even months. During this process, the carbonic acid is evolved in very small bubbles, and the yeast settles at the *bottom* of the vessel, (*bottom fermentation*, *bottom yeast*). The beer thus prepared contains scarcely a trace of gluten or yeast, and therefore can be kept for years without becoming sour; it is, moreover, richer in carbonic acid than that obtained by the process of surface fermentation, because in consequence of the lower temperature, and the more gradual elimination of the carbonic acid gas, it is able to retain more of the latter. The stronger kinds of beer (*Bavarian beer*, *strong beer*, &c.) are made in this way. The thick bottom yeast, separating during this process, acts indeed as an exciter of

fermentation upon the sugar, but far more slowly and gently than the frothy surface yeast.

490. The peculiarities of the two methods of fermentation may be elucidated as follows:

Surface Fermentation	*Bottom Fermentation*
a.) takes place at a higher temperature, 53° F. (12° C.), 68° F. (20° C.);	at a lower temperature, 41° F. (5° C.), 50° F. (10° C.)
b.) takes place rapidly (in three or four days);	slowly (in six or eight weeks).
c.) in this case imperfect separation of the yeast by flowing over;	in this case thorough separation of the yeast by settling.
d.) surface yeast is finely divided and frothy;	bottom yeast is compact and heavy.
e.) surface yeast is a strong exciter of fermentation;	bottom yeast a feeble exciter of fermentation.
f.) surface-fermented beer soon becomes sour;	bottom-fermented beer does not.
g.) surface-fermented beer contains but little carbonic acid;	bottom-fermented beer more.
h.) serves for the manufacture of weak beer;	serves for the manufacture of strong beer.
i.) by lowering the temperature, the surface fermentation may be converted into bottom fermentation.	by raising the temperature, the bottom fermentation may be converted into surface fermentation.

Experiment.—Subject a weighed or measured quantity of beer to distillation (§ 486); weak *alcohol*, together with carbonic acid, will first pass over, and finally only a watery liquid. Pour the yet fluid residue into a cup, and set it in a warm place; it dries up, forming a dry amorphous mass (*extract of beer*), which consists principally of *dextrine*, *sugar*, and the *bitter principle of hops*. By determining the strength and the quantity of the alcohol, and the weight of the extract obtained, we have the two most important factors for estimating the nature and quality of the beer.

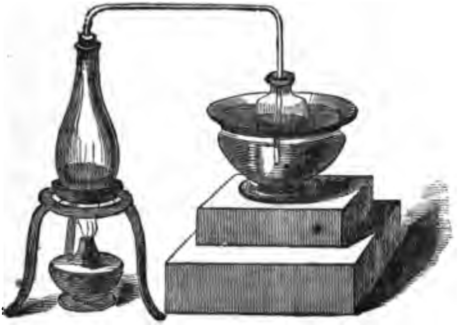
SPIRIT.

491. The *preparation* of spirit is similar to that of beer, inasmuch as substances containing starch are also employed in the preparation of it, and as the starch must first be converted into sugar before the fermentation can proceed. This is done, as in the case of beer, by the mashing process—that is, by the operation of the diastase of the malt upon the starch. To this end either boiled and mashed potatoes or rye are

mixed with bruised barley-malt and hot water, so as to form a paste, which is to be kept at a temperature of 158° F. (70° C.) until a complete formation of sugar is effected; then brewers' yeast (surface yeast) is added to the sweet mash or wort previously cooled, whereby fermentation is induced. When this fermentation is concluded, put the mass into a copper still, and distil the volatile alcohol from the non-volatile parts (husks, gluten, fibrous matter, &c.). The residue is used as a nourishing food for the fattening of cattle. Formerly simple retorts were used for this distillation, and a weak spirit was obtained, which consisted of about one-third of alcohol and two-thirds of water; but now a more complicated apparatus is universally employed, by means of which a spirit of double the strength is obtained (*rectified spirit*). The principle upon which this apparatus depends will be explained in the following experiment.

492. *Rectification or strengthening of Spirit.—Experiment.*—Pour three ounces of common spirit of wine into a capacious flask, and carefully distil half of it into a vessel, which is cooled by means of very cold water, or what is still better, by ice. If the spirit contained thirty per cent. of alcohol, then the ounce and a half of alcohol first passing over will contain at least fifty per cent. Alcohol is *more volatile* than water; therefore it passes over first, in company with a smaller quantity of the latter, while the greater part of the water, together

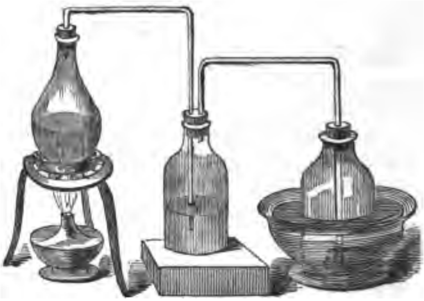
Fig. 192.



with the fusel oil which might have been contained in the spirit, remains behind in the flask (*phlegm*).

493. *Experiment.*—If you connect with the flask and the receiver an intermediate vessel, a wide-mouthed bottle, for instance, which is easily done by means of two glass tubes bent at right angles, and a cork perforated with two holes, and then repeat the above experiment of distillation, the alcoholic vapours passing over will first condense in the middle vessel. But, as this vessel is not cooled down, the liquid condensed in it will finally also boil, and the vapours thus formed will pass over into the receiver surrounded with cold water, and will there be condensed for the second time. In this manner a double distillation (rectification) is effected. The flask contains boiling spirit (at 30° Tralles*); the intermediate vessel, boiling rectified alcohol (at about 50° Tralles). After the termination of the experiment, the first vessel will contain phlegm; the second, weak spirit; and the third, very strong, highly-rectified spirit (of 70° to 80° Tralles).

Fig. 193.



If you adapt to the corks of the first two vessels a couple of thermometers, which shall dip into the liquid, you will find that the liquid in the flask boiled at the commencement of the experiment at 185° F. (85° C.), and at the end of the experiment at from 203° F. (95° C.) to 212° F. (100° C.), while that contained in the second vessel commenced boiling at 176° F. (80° C.), and ended with boiling at from 185° F.

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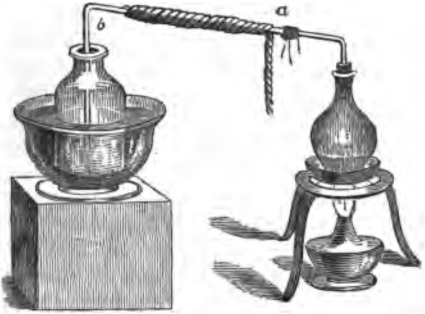
* The alcoholometer of Tralles floats to a figure on the stem, which indicates the percentage of alcohol, *by volume*, in the liquor in which it is placed.

(85° C.) to 194° F. (90° C.) It is obvious from this that strong spirit boils at a much lower temperature than that at which weaker spirits boil. The strongest alcohol (absolute) boils at 172° F., consequently at forty degrees lower than water.

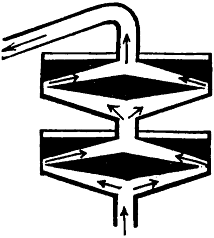
494. *Experiment.*—Connect with a flask a tolerably large glass tube, which is so bent that its middle part has a slight inclination upwards, as is shown in the annexed figure; from *b*, this tube is wound round with moistened wick-yarn, the end of which hangs down at *a*. At *a*, bind a strip of cloth (several times folded together and smeared with a few drops of olive-oil) round the tube, so that the water from the wick may not run down upon the flask. Now distil as before three ounces of spirit, but during the distillation continually drop cold water upon the wick-yarn, at *b*, in order to cool the vapour of the spirit as it passes over. Catch the water runing down the outside of the tube in a vessel placed below the end of the wick-yarn. If the distillation is arrested when about one ounce of the spirit has passed over, we shall have a stronger spirit in the receiver than was obtained in the experiment in § 492, because, by the partial cooling of the vapour of the spirit, the principal part of the less volatile aqueous steam was condensed, and, therefore, a vapour richer in alcohol passed into the receiver, while the water condensed in the tube flowed back into the flask.

Fig. 194.



This principle of *partial refrigeration* has been most successfully applied to the distillation of spirit on a large scale. The best-known apparatus used for this purpose is called the *dephlegmator*, and is so contrived that the hot vapours rising from the still must pass through several copper channels before reaching the refrigerator; these channels have a partition in the centre, and are kept cold externally by a constant current of water. We obtain in this way a spirit of from 70° to 80° Tralles, while a simple still yields only a weak spirit of 30° Tralles.

Fig. 195.



495. Alcohol is rendered not only *stronger*, but *purer*, by the above-mentioned rectification. Besides alcohol, there is formed from grain and potatoes, during fermentation, an oily, disagreeably smelling liquid, the so-called *fusel oil*, and also some vinegar. Both are less volatile than alcohol, and therefore, during the above rectification, are for the most part condensed with the water, which flows back. The *phlegm* is accordingly a mixture of water with alcohol, fused oil, and vinegar. The alcohol may be thoroughly purified from the fusel oil by letting it stand for some time in contact with freshly burnt charcoal, and then filtering it; the fusel oil remains behind in the pores of the charcoal. (§ 105.) It is still more advantageous to let the alcoholic vapours, before their condensation after distillation, pass through a cylinder filled with charcoal, and applied over the dephlegmator.

496. In the same way that spirit and brandy are made here from grain and potatoes, a spirituous liquor called *arrack* is prepared in the East Indies from rice, by mashing, fermenting, and distilling, and mixing with it the seeds of the catechu palm-tree, thus imparting to it a peculiar flavour, and an odour resembling that of rum.

497. All fermented liquors contain alcohol, and owe to this their intoxicating power. The quantity of it contained in our ordinary spirituous liquors is shown in the following table:

			Pure Alcohol.	
In 100	measures	of common beer are contained	1½ — 2	measures.
"	"	strong beer,	3 — 5	"
"	"	porter or ale,	9 — 8	"
"	"	wine,	10 — 15	"
"	"	Madeira wine,	18 — 24	"
"	"	brandy,	40 — 45	"
"	"	liqueur,	45 — 50	"
"	"	rum or arrack,	50 — 60	"
"	"	rectified spirit,	60 — 70	"
"	"	alcohol,	70 — 75	"
"	"	highly rectified alcohol,	86 — 90	"

ALCOHOL.

498. *Anhydrous Alcohol.*—Alcohol has as yet only been obtained by the fermentation of sugar. In the preceding chapters we have already shown how alcohol is formed, how it is rendered stronger, and how it is purified. This is done by partial distillation, or by partial condensation, since the alcohol is more difficult to volatilise than water, whilst its vapour is more difficult to condense than steam. But all the water cannot be separated in this way from the alcohol, as the alcohol retains one-tenth part of the water so firmly that it can neither be withdrawn from it by distillation nor by cooling. In order to procure it absolutely anhydrous, a body must be presented to it which has a greater affinity for water, and fixes it so firmly, that it cannot evaporate with the alcohol at the boiling point of the latter. Such a body is quicklime.

Experiment.—Put into a flask one ounce of quicklime that has been broken into small pieces, and pour upon it one ounce of very strong alcohol; connect a receiver with the flask, as in the experiment in § 492, and let the mixture remain in repose for one day. The lime gradually combines with the water of the alcohol (it slakes), and the latter is procured anhydrous by distilling it off at a moderate heat. The best method of distilling in this case is over the water-bath (Fig. 83). *Anhydrous* alcohol is also called *absolute alcohol.* In this experiment, the vessels used must be previously rinsed out, not with water, but with strong alcohol, because the moisture adhering to the vessel would again impart water to the anhydrous alcohol.

499. *Properties of Alcohol.*—Alcohol has a burning taste, and a penetrating, agreeable odour. Strong alcohol, especially absolute alcohol, acts as a poison when swallowed; but when diluted, it is, as is well known, stimulating and intoxicating.

Strong alcohol has never been *frozen*, even at a cold of —212° F (—100° C.); it is therefore excellently adapted for the making of thermometers by which great degrees of cold are to be measured. For this reason it is likewise serviceable in the illuminating-gas apparatus, for preventing in winter the freezing of the water which settles in the gas-pipes, and the consequent obstruction of the pipes. The illuminating-gas, on leaving the gasometers, is first made to pass through alcohol before it is conducted further, whereby the watery vapour is not only withdrawn from the gas, but so much vapour of alcohol is also added to it, that the liquid now condensing in the pipes does not freeze at the temperature of our winters.

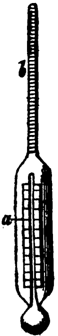
If common alcohol is placed in an open vessel, the alcohol *evaporates* more rapidly than the water contained in it. Strong alcohol also attracts water from the air. Thus is explained why all spirituous liquids must, when in unclosed vessels, lose strength, and become richer in water. The young chemist is frequently reminded of this fact in the case of the spirit-lamp; it will not burn when it has remained exposed to the air for some time unprotected. Why not? The spirit has passed away through the wick, the phlegm remaining behind.

The *boiling* and *evaporation* of alcohol have already been treated of at §§ 493 and 494, and the *combustion* of it in § 121. Alcohol contains so little carbon, that no soot is separated during its combustion; hence, also, the alcohol flame emits but a feeble light. The strength best adapted for spirit used in burning is that from 75° to 80° Tralles; if weaker, all the water will not evaporate during the combustion, and phlegm remains behind.

500. Alcohol may be mixed with *water* in every proportion, and it becomes specifically heavier the more water it contains; therefore, its specific gravity is a very simple, and at the same time a sure, test for the greater or less strength of alcohol. This is most conveniently ascertained by the areometer *(alcoholometer)*. Absolute alcohol has a specific gravity of 0.792; that is, a vessel capable of containing just 1000 grains of water is entirely filled by 792 grains of absolute alcohol; it is accordingly about one-fifth lighter than water. In this alcohol, the alcoholometer sinks to the topmost point of the scale, to 100°, while in pure water it sinks to the lowest degree of the scale, which is marked 0°. (§ 16.) The scales most in use in Germany are

those of *Tralles* and *Richter*, which deviate very widely from each other, since *Tralles* made the mixtures of alcohol and water from which he determined the degrees by *measure* or *volume*, while *Richter* made them by *weight*. The former, for instance, called that alcohol which consisted of one measure of alcohol and one measure of water, *fifty degrees;* but the latter gave this number to a mixture consisting of one pound of alcohol and one pound of water. There must, of course, be more alcohol in the latter than in the former mixture, because one pound of alcohol occupies a greater volume than one pound of water; and thus is explained why one and the same alcohol shows more degrees on Tralles's alcoholometer, and consequently appears stronger than by Richter's.

Fig. 196.



If you mix 50 measures of alcohol and 50 measures of water, you do not obtain 100 measures, but only about 97; thus a *condensation* takes place, as in the mixing of sulphuric acid with water. (§ 173.) This explains the heating which always takes place when water and alcohol are mixed together. The knowledge of this fact is of economical importance for those merchants who now frequently prepare brandy by diluting strong spirit with water, since this liquid is commonly sold by measure.

501. Alcohol, like water, is a *solvent* for many substances, and, indeed, it not only dissolves many substances, which are also soluble in water, such as tannin, sugar, &c., but many others, which are insoluble or nearly insoluble in water, such as resins, volatile oils, &c.

Experiment.—Pour into a bottle, containing one drachm of bruised *gall-nuts*, an ounce of water, and into another bottle, containing the same quantity of gall-nuts, an ounce of alcohol; tie over both flasks a piece of moistened bladder, in which some holes have been pierced with a needle, and set them aside for some days in a warm place. We obtain in both cases dark-coloured, very astringent-tasting liquids *(infusions and tinctures)*, which are to be clarified by filtration. They both hold in solution a peculiar principle of gall-nuts, called *tannin* or *tannic acid.* The watery infusion will decompose after a time, with the formation of vegetable mould; but not so the spirituous tincture, because alcohol has the power of preventing the occurrence of putrefaction.

Experiment.—Prepare in the way just described an infusion from one drachm of powdered ***cinnamon*** and water. A slightly coloured liquid is obtained, and this, if evaporated on a warm stove, leaves behind an almost tasteless gum, which easily dissolves again in water. Now pour some alcohol upon the cinnamon that remains, and let them digest for several days; we shall obtain a dark-brown, fiery, spicy, and astringent-tasted liquid (*tincture of cinnamon*). If some of this tincture is evaporated to dryness, a brown, glistening mass (***resin***) remains behind, which may be redissolved in alcohol, but not in water. Besides several other substances, the water has accordingly dissolved principally gum, the alcohol principally resin (and volatile oil) from the cinnamon.

These examples are sufficient to show in how many ways alcohol may be employed as a means of solution and preservation. The principal solutions effected by it are,—

a.) The ***tinctures*** of pharmacy, alcoholic extracts of medicinal plants, roots, barks, &c.

b.) The ***lac varnishes***, solutions of resin in alcohol.

c.) The so-called ***perfumed waters***, eau de Cologne, solutions of volatile oils in alcohol, &c.

d.) The ***liqueurs and cordials***, solutions of volatile oils (oil of cumin, oil of peppermint, &c.) sweetened with sugar, or of bitter and aromatic substances (cloves, orange-peel, &c.), in alcohol.

Two of the various changes which alcohol may undergo are specially important, namely, its conversion into ***ether*** and ***vinegar***.

VII. CONVERSION OF ALCOHOL INTO ETHER.

502. *Elayle, or Olefiant Gas.*—*Experiment.*—Mix very gradually, and with constant stirring, two ounces of common sulphuric acid with half an ounce of strong alcohol (§ 84); the heating which ensues on the union of these two fluids is still greater than that which takes place on mixing together sulphuric acid and water. When the mixture is cold, pour it into a flask, and heat it in a sand-bath (see Fig. 84), at first cau-

tiously, that it may not rise over, and afterwards somewhat more strongly; a kind of gas is evolved, which has to be collected, as has been described, in bottles filled with cold water. Inflame the gas contained in one of the bottles, and immediately pour in water; it burns with a highly luminous flame; it is *illuminating gas* ($C_4 H_4$), which is formed from the alcohol. The alcohol is resolved into *illuminating gas* and *water*, which latter combines with the sulphuric acid remaining behind.

Fig. 197.

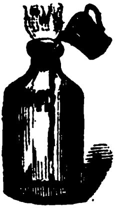
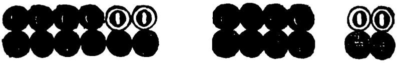


Fig. 198.



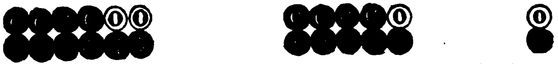
There is formed from alcohol, illuminating gas and 2 water.

There are likewise formed at the same time sulphurous and carbonic acids, the former of which may easily be recognised by the smell; they are generated by the carbon of a portion of the alcohol decomposing a portion of sulphuric acid, and abstracting from the latter its oxygen. In order to purify the illuminating gas from these two volatile acids, it has only to be conducted through milk of lime before it is collected.

The illuminating gas thus obtained has received the name of *elayle*, or *olefiant* gas, because it condenses with chlorine, forming an ethereal liquid, like oil, insoluble in water.

503. *Sulphovinic Acid.—Experiment.*—Mix one ounce of strong alcohol with one ounce of common sulphuric acid, but now without cooling the vessel by cold water, because by the heating of the mixture the desired chemical change is promoted. That such a change has really taken place is known by the peculiar smell, different from that of alcohol, and by the altered (brownish) colour of the liquid. The change which a portion of the alcohol has hereby experienced is as follows:

Fig. 199.



There is formed from alcohol, ether (oxide of ethyle), and 1 water.

While in the former experiment, by an excess of sulphuric acid, two atoms of oxygen and two atoms of hydrogen were separated from the alcohol, in the latter case the alcohol loses only half as much of these two elements, namely, one atom of each, which two combine to form water. From the alcohol ($C_4 H_6 O_2$) there is formed a new body ($C_4 H_5 O$) which has received the name *oxide of ethyle* (Ae O), because it is able, like a base, to combine with acids. In the present case the oxide of ethyle meets with free sulphuric acid, with which it combines, forming *bisulphate of oxide of ethyle* ($Ae O, 2 S O_3 + 4 H O$). This compound is more simply designated by the name of *sulphovinic acid.*

504. *Ether.*—If the liquid of the preceding experiment, containing the sulphovinic acid, is heated, it resolves itself into oxide of ethyle (ether), water, and sulphuric acid.

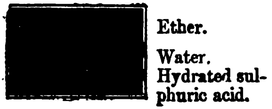
Experiment.—Put the mixture prepared from alcohol and sulphuric acid into a flask connected with a glass tube and a receiver (see Fig. 106), close the opening remaining between the neck of the receiver and the glass tube by binding round it a piece of moistened bladder, in which some fine holes are pierced, and heat the flask *carefully* in a sand-bath till the contents of it assume a bubbling motion. Maintain the boiling of the liquid till about half, or at most three-quarters, of an ounce of the liquid is distilled over. In this experiment the liquor, as it is distilled, must be subjected to a powerful refrigeration, because it is extremely volatile; it is therefore advisable *to perform the experiment in winter*, and to surround the receiver with snow. Care must also be taken not to bring any burning substance too near the vapours of the liquid which pass over, as they are both *exceedingly inflammable.* The distilled, colourless liquid possesses a penetrating, pleasant smell; it is called *crude ether.*

In order to purify it, shake it up in a small vessel with half an ounce of water, and one drachm of potassa lye; close the vial, and let it remain standing for an hour with the bottom upwards. Crude ether contains a mixture of water, alcohol, and frequently also, when the distillation is continued too long, some sulphurous acid; these substances combine with the water and the potassa added, and form with them the heavier liquid layer, which settles at the bottom of the phial. The very thin and mobile liquid floating above is *ether*, which separates, because it comports itself towards water in the same manner as oil does, and is dissolved by it only in very small quantity. If you now loosen the stopper of the inverted phial, the aqueous liquid will run out, while the ether remains behind. If the latter is required entirely pure, it must be again distilled or rectified.

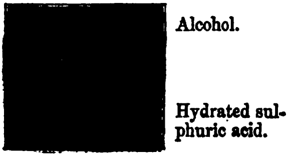
The most profitable way of preparing ether on a large scale is the following: Nine pounds of sulphuric acid and five pounds of alcohol are mixed together, and heated to the boiling point. While the mixture is still boiling, just so much alcohol is allowed gradually to drop in, as there is ether distilled over. One single pound of sulphuric acid is then sufficient gradually to convert into ether thirty pounds of alcohol, at ninety per cent., or an unlimited quantity of absolute alcohol.

505. *Explanation of the Formation of Ether.*—Alcohol is distinguished from ether merely by this, that it contains one atom of hydrogen and one atom of oxygen, consequently one atom of water, more than the latter. Accordingly, the production of ether might be explained in the simplest manner thus: sulphuric acid, on account of its strong affinity for water, abstracts from the alcohol one atom of water, and thus the alcohol is converted into ether. But the process is somewhat more complex, because there is an intermediate station—the bisulphate of oxide of ethyle—on the way between the alcohol and the ether. This complex compound, having the character of a salt, acts very differently according as it is heated in a concentrated or in a diluted condition. When diluted with six, or, at most, with eight atoms of water, this compound boils at from 266° F. (130° C.) to 284° F. (140° C.), and is thereby resolved into ether, water, and hydrated sulphuric acid; the two former volatilise without combining chemically with each other, and the latter remains behind. When the bisulphate of the oxide of ethyle is diluted with from nine to ten atoms of water, it boils even at a lower temperature than 266° F. (130° C.), and is thereby resolved into alcohol and hydrated sulphuric acid. Here, too, ether and water are first separated, but both, when in a nascent state, combine chemically with each other, forming alcohol. This is the reason why, in the last-mentioned me-

At 266° to 284°.



Below 266°.



thod of preparing ether, the sulphuric acid becomes ineffectual after it has transformed thirty times its own weight of alcohol at ninety per cent. into ether; it has then become so diluted by the water which it has abstracted from the hydrated alcohol, that nearly nine atoms of water have combined with two atoms of sulphuric acid. It has already been shown, in the first part of this work, by several experiments, how other bodies also, at different temperatures, evince sometimes a stronger, sometimes a weaker affinity for water, or, indeed, none at all for it.

506. *Experiments with Ether.*

a.) Pour some drops of ether upon the hand; it will evaporate in a few moments, imparting to the hand a perceptible feeling of coldness. (§ 40.) Ether is so *very volatile* that it boils when in summer it is put in the sun at 95° F. (35° C.); therefore it must always be kept in tightly closed bottles, and in a cool place.

b.) Dip one piece of wood into ether, another into alcohol, and hold both to the flame of a candle; the ether *burns* with far greater briskness, and also with a much more luminous and a somewhat fuliginous flame. Its stronger illuminating power is simply explained by its containing a larger amount of carbon. The process in burning is the same as with alcohol; the ether being also converted into carbonic acid and water.

c.) If you pour some drops of ether into a tumbler, and after some minutes, when the ether is converted into vapour, apply to it a burning taper, a sudden ignition ensues, accompanied by an explosive noise. The vapour of ether forms, like hydrogen or marsh gas, when mixed with atmospheric air, a kind of *explosive gas*, and several violent explosions have been occasioned by carrying lighted candles or lamps into those places where, owing to the breaking of a bottle filled with ether, its vapour has become diffused in the air.

d.) Ether may be mixed with alcohol in any proportion whatever. When mixed with three parts of alcohol, it is much used as a stimulating and restorative medicine, under the name of *Hoffmann's anodyne liquor*.

e.) Put a piece of *tallow*, or a few drops of olive oil, into a test-tube with some ether; both will entirely dissolve in it. But they are not soluble in alcohol or water. Therefore ether may be advantageously employed for dissolving and separating such substances as will dissolve in it, but not in other liquids.

Besides fat, many of the resins, and the so-called gum elastic (caoutchouc), are soluble in ether.

Ether is also very generally called *sulphuric ether;* but this appellation is incorrect, since pure ether neither contains sulphuric acid, nor has any sulphur in its composition.

507. *Combinations of Ether with Acids.*

It has already been stated, that ether, though it does not give a basic reaction, yet comports itself as a base, that is, combines with acids. These combinations, however, cannot be directly produced by the mixture of ether with acids. Ether combines with acids at the moment of formation only, or when it is liberated from some other combination; but after it has once been set free, it no longer shows any inclination to combine with acids. These combinations may be called salts of ether, or salts of oxide of ethyle, just as the terms salts of potassa and salts of potassium are used, but they are generally spoken of as *kinds of ether.* Most of them are liquid, and have a volatile, cooling taste. They are commonly prepared by distilling the different acids with alcohol, and often with the aid of sulphuric acid. Those only which are best known will be here alluded to.

Acetate of Oxide of Ethyle, or *Acetic Ether* ($Ae\ O, \bar{A}$), is a very volatile liquid, having an agreeable odour, and is employed in medicine.

Nitrite of Oxide of Ethyle, or *Nitrous Ether* ($Ae\ O, N\ O_3$), has an agreeable odour, like that of fruit, and is contained, diluted with alcohol, in the *spir. nitr. æth.* (sweet spirits of nitre) of the apothecaries, which is known as a medicine.

Chloride of Ethyle, or *Muriatic Ether* ($Ae\ Cl$), forms a constituent of the spirit of muriatic ether.

Œnanthate of Oxide of Ethyle, or *Œnanthic Ether* ($Ae\ O, \bar{O}e$), is contained in wine, and is the cause of the so-called bouquet of certain sorts of wine.

Butyrate of Oxide of Ethyle, or *Butyric Ether*, now occurs in commerce under the name of rum-ether, or essence of rum, and is used for imparting to alcohol an odour similar to that of rum.

508. *Organic Radicals.*

Formerly organic substances were considered as immediate combinations of carbon, hydrogen, oxygen, nitrogen, &c.; accordingly they were divided into ternary compounds (having three elements), quaternary (having four elements), &c. But in modern times the hypothesis has been adopted, that a simple manner of combination may exist in organic substances analogous to that of the inorganic compounds; namely, that a simple group of atoms, as of carbon and hydrogen, may comport itself in the same way as an element or a radical; the group $C_2 N$ (cyanogen), for instance, comports itself as such. This supposition has already been most beautifully confirmed in many cases, and since alcohol and ether, and their metamorphoses, are peculiarly adapted for illustrating this new mode of considering the subject, we will cite them as examples. In these combinations we consider a group of four atoms of carbon and five atoms of hydrogen ($C_4 H_5$) as the elementary substance, as the radical, and call it *ethyle* (Ae). Accordingly, we now regard ether ($C_4 H_5 O$) as oxide of ethyle ($Ae + O$); alcohol ($C_4 H_6 O_2$) as hydrated oxide of ethyle ($Ae\ O + H\ O$); sulphovinic acid as bisulphate of oxide of ethyle ($Ae\ O, 2\ S O_3 + 4\ H\ O$); acetic ether as acetate of oxide of ethyle ($Ae\ O, \bar{A}$); muriatic ether as chloride of ethyle ($Ae\ Cl$), &c.

It will be readily perceived from this grouping, that the organic compounds show a surprising resemblance to the inorganic, and may be very well compared with them; the ethyle series, for instance, with the potassium series, in the following manner:

Potassium	corresponds	to	ethyle,
Potassa	"	"	oxide of ethyle (ether),
Hydrate of potassa	"	"	hydrated oxide of ethyle (alcohol),
Bisulphate of potassa	"	"	bisulphate of oxide of ethyle,
Acetate of potassa	"	"	acetate of oxide of ethyle (acetic ether),
Chloride of potassium	"	"	chloride of ethyle, &c.

The radicals of this kind, among which may be reckoned, also, cyanogen and ammonium, are termed *compound* or *organic radicals*. Ethyle belongs to the division of radicals *forming bases*.

VIII. CONVERSION OF ALCOHOL INTO VINEGAR.

509. *Experiment.*—Mix in a glass vessel half an ounce of brandy with three ounces of spring-water, and put in the liquid a slice of leavened rye bread, which has been previously soaked in strong vinegar, or instead of it a little leaven; cover the vessel with a piece of perforated pasteboard, and put it in a place where the temperature is between 86° F. (30° C.) and 104° F. (40° C.); the spirituous liquor will, after some weeks, be converted into vinegar. This conversion does not take place in a closed vessel, as the oxygen of the air is indispensable to the process; a great quantity of oxygen is consumed, since the *formation of vinegar consists in an oxidation of the alcohol by the oxygen of the air.* Neither is any vinegar formed if you do not add the bread or the leaven. As a solution of sugar does not of itself pass over into alcohol, neither does the alcohol of itself pass over into vinegar. But as an easily resolvable body (ferment, yeast, &c.) disposes sugar to enter into decomposition simultaneously with itself, so also acid bodies, that may be easily decomposed, such as black bread, leaven, vinegar, &c., are able to bring the alcohol into that state in which it absorbs oxygen. The mode of action of these substances, which are called vinegar ferments, resembles that of the nitric oxide in the sulphur-chambers; they are, like the latter, *the transferrers*, that is, they attract the oxygen from the air, and give it up again to the diluted alcohol.

In the same manner with pure diluted alcohol, all other *alcoholic liquids*, as beer, wine, cider, &c., may, by receiving oxygen, be converted into vinegar, and it is well known that vinegar is frequently prepared from them. If, as is ordinarily the case, they contain gluten or lees in solution, then these substances replace the vinegar ferment, and the acidification ensues spontaneously, when the liquid is exposed in loosely covered vessels to a temperature of from 86° F. (30° C.) to 104° F. (40° C.) This acidification most readily occurs immediately after a spirituous fermentation, which has taken place at too high a temperature; for this reason, in the hot months of summer, the brewers and distillers find difficulty in keeping their fermenting wort and mash from turning sour, which can only be prevented by rapid refrigeration.

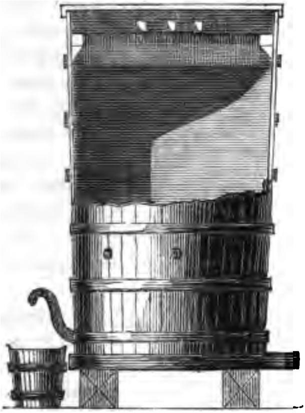
Liquids, also, containing *starch* and *sugar*, may pass over into vinegar, but only after these have been previously converted by fermentation into alcohol. This explains why the farmer obtains vinegar, when, having poured water upon the peels and refuse of fruit, he sets them aside near the stove; why boiled food, preserved fruits, &c., become acid after a time. The spirituous fermentation, which first takes place, is always followed by an effervescence or fermentation in these cases, because the carbonic acid, formed from the sugar at the same time with the alcohol, escapes. From this is derived the term *acetous fermentation*, by which, in earlier times, the process of the formation of vinegar was designated, this effervescence being regarded as an essential phenomenon in the generation of vinegar. But it is now known that no evolution of gas takes place during the conversion of alcohol into vinegar.

510. *Experiment.*—fill two tumblers loosely with the stalks of grapes, and fill one entirely and the other only half full with wine, beer, or a mixture consisting of one part of brandy, one part of beer, and six parts of water. Put both vessels in a warm place, and once or twice every day pour the mixture from one vessel into the other, so that each may be alternately full and only half full of the liquid. The alcohol contained in the brandy will, in this manner, be much more rapidly oxidised into vinegar, because the liquid adhering to the grape-stalks is, in this state of fine division, surrounded by air, and thus has a far better opportunity of attracting oxygen from the latter. The effervescence taking place at the commencement was owing to the sugar contained in the beer and the grape-stalks, and which was first converted into alcohol and carbonic acid. The alcohol thus formed was likewise afterwards changed into vinegar, and this is the reason why the vinegar thus produced is more acid, that is, richer in acetic acid, than that obtained by the former experiment.

511. *Quick Method of making Vinegar.*—The transition of alcohol into acetic acid takes place still more rapidly by subdividing the alcohol still further, or by exposing a still greater surface of the liquid to the air than in the way just described. This is effected in the following manner:

A tub four or five yards high is filled with shavings of beech-wood, and is furnished with a perforated shelf, which is placed somewhat below the upper opening. Through each of the small holes a straw or a piece of packthread is passed, prevented from falling through by a knot at the upper end. By this means an extreme division of the alcohol is effected, as when it is poured in at the top, it only trickles slowly down through the holes by means of the straw or packthread, and then diffuses itself over the shavings, forming a very thin liquid layer, which presents to the air a surface many thousand times more extensive than was produced by any former method. Several large holes are bored round the lower part of the tub, and likewise in the perforated shelf; glass tubes are fitted into the holes made in the latter, in such a manner that the liquid, when poured into the top, may not run off through them. A free circulation of air is hereby produced, the cooler air enters by the openings in the tub, gives up its oxygen to the alcohol diffused over the shavings, and, in consequence of this oxidation, or slow combustion, so much heat is evolved in the interior of the tub, that the temperature rises to 104° F. (40° C.) The air, hereby becoming warmer, and consequently lighter, passes out of the tub through the glass tubes in the shelf, and from an eighth to a fourth poorer in oxygen than when it entered. Strong vinegar is used as a ferment in this process, the tub and shavings having previously been moistened with it, and a certain quantity being also added to the mixture of spirit which is to be converted into vinegar. In such a tub (*vinegar-generator*), warmed spirit, beer, wine, &c., may be converted into vinegar in a few hours, by being passed through the cask three or four times; hence this is called *the quick method of making vinegar*.

Fig. 200.



512. *Explanation of the Process of forming Vinegar.*—In order to convert alcohol into vinegar, four atoms of oxygen

must enter into combination with one atom of alcohol. From one atom of alcohol and four atoms of oxygen, $=C_4H_6O_2+4O$, are formed one atom of acetic acid and three atoms of water, $=C_4H_3O_3+3HO$. The alcohol is accordingly oxidised into acetic acid and water.

This process may be regarded as a slow and imperfect combustion, and we shall here also find confirmed what was stated of the combustion of wood in the air (§ 120), and of the combustion of sugar by nitric acid (§ 196); namely, that the easily combustible and easily oxidised hydrogen combines with the oxygen before the difficultly combustible carbon does. Here, as is obvious, none of the carbon of the alcohol is consumed, but one-half of its hydrogen is consumed or oxidised by the oxygen of the air, one atom of oxygen, moreover, being taken from the air.

Aldehyde.—We have thus far considered only the starting-point (alcohol) and the extreme point (acetic acid) of the process of the formation of vinegar; but half-way between these two there is a peculiar compound, which may be regarded as half-converted alcohol, or half-made vinegar. It is formed from the alcohol when two atoms of oxygen enter into combination with it, thereby converting two atoms of its hydrogen into water. The name *aldehyde* (that is, *al-* alcohol, *de-* from which, *hyd-* hydrogen is taken) has been given to it.

From alcohol, $=C_4H_6O_2$ and $2O$,
is formed aldehyde, $=C_4H_4O_2$ and $2HO$.

This compound is always produced in the first period of the formation of vinegar, and occasions the peculiar suffocating smell often perceived in vinegar-chambers. *Aldehyde* very greedily attracts two more atoms of oxygen from the air, and is thereby converted into hydrated acetic acid ($HO, C_4H_3O_3$). This occurs in the second period of the formation of vinegar, when an acid odour prevails in the vinegar-chambers.

Aldehyde may be very easily produced, and it may be readily recognised by its characteristic odour, when, as was directed in § 114, a glowing platinum wire is held in alcohol vapour, or yet more easily, by pressing down an alcohol flame by a wire net. In both cases it is formed because the temperature is not high enough to effect a complete combustion of the alcohol vapour. A portion of the latter then takes up only two atoms of oxygen from the air, and there is produced aldehyde vapour, and, together with this, some acetic acid and other gaseous products.

After this statement of the process of the formation of vinegar, it will no longer appear strange that aldehyde and acetic acid are formed in all cases when alcohol unites with bodies which are rich in oxygen, and which readily part with it, as, for instance, chromic acid, nitric acid, black oxide of manganese, sulphuric acid, &c.

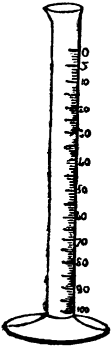
It may now also be easily explained how vinegar is produced from wood by dry distillation. Wood consists of $C_6 H_5 O_5$; acetic acid of $C_4 H_3 O_3$, or, if multiplied by 1½, of $C_6 H_{4\frac{1}{2}} O_{4\frac{1}{2}}$. Consequently, it is only necessary to abstract a little hydrogen and oxygen from the wood, in order to transfer it into acetic acid.

513. *Acetyle.*—Aldehyde and acetic acid may, like ether and alcohol, be regarded as combinations of an organic radical. This radical is called *acetyle* (Ac), and it is assumed to be composed of four atoms of carbon and three atoms of hydrogen ($C_4 H_3$). Accordingly, aldehyde ($C_4 H_4 O_2$) is the same as hydrated oxide of acetyle ($Ac + O + H O$); acetic acid ($C_4 H_3 O_3$) is the same as oxide of acetyle ($Ac + 3 O$).

Acetyle belongs to the class of *radicals forming acids.*

514. *Properties of Vinegar.*—Vinegar is acetic acid diluted with much water, and frequently mixed also with foreign substances, which it obtains from the malt, fruit, wine, &c., from which it is prepared. The esteemed yellow or brownish colour is often imparted to it artificially by burnt sugar, or extract of chicory. The vinegar which occurs in commerce under the name of white vinegar contains in every hundred measures from eight to twelve measures of acetic acid, wine, vinegar from six to eight, and common table vinegar only from two to five; the rest is water. In order to ascertain the strength of vinegar, we adopt a course similar to that used in testing carbonate of potassa (§ 202); that is, we examine how much of some base (ammonia is the best) a fixed quantity of it is able to neutralise. Glass cylinders, constructed for this purpose, and divided into degrees, are called *acetometers.*

Fig. 201.



If vinegar is allowed to remain for some time exposed to the air, it begins to decompose (to putrefy), and so much the more readily the weaker it is. This is indicated sometimes by a white film (*mould*), sometimes by the separation of gelatinous matter (*vinegar mother*), sometimes by the generation of infusoria, which can often be distinguished by the naked eye when a glass of vinegar is held towards the sun (*vinegar eels*). Further decomposition may be arrested for a time by boiling the vinegar.

Vinegar is somewhat *less volatile* than water. When it is distilled, first a weaker, and finally a stronger, colourless vinegar passes over (*distilled vinegar*), and the foreign non-volatile mixtures remain behind.

When vinegar is exposed to the *cold*, the water contained in it is frozen before the acetic acid is; hence, weak vinegar may be made stronger by partial freezing. Wine, when exposed to the cold, acts in the same manner.

To impart to vinegar a more pungent or more acid taste, such substances as Spanish pepper, pellitory root, and, indeed, sulphuric acid, are sometimes added to it. The latter adulteration may readily be detected in the following manner:

Experiment.—Fill a jar half full of water, and place upon it a cup containing the vinegar to be tested, together with some grape-sugar; then let the jar remain on a hot stove till the vinegar has evaporated. If the residuum is of a black colour, then the vinegar contains sulphuric acid. When heated over hot water, the vinegar only is volatilised, while the sulphuric acid, if any is present, remains behind, and finally, when all the aqueous particles have vanished, attains such a strength, that it decomposes the sugar and chars it.

Fig. 202.

CONVERSION OF SUGAR INTO LACTIC AND BUTYRIC ACIDS.

515. If an open vessel, containing some expressed juice of the beet, is put in a warm place, where it will be heated to between 86° F. (30° C.) and 104° F. (40° C.), the beet-juice will enter into fermentation, in the same manner as in § 482; but when the fermentation is finished, notwithstanding that all the sugar has disappeared, we do not find any alcohol in the fermented liquid, but a peculiar acid (*lactic acid*), and a mucilaginous gummy substance. This process of decomposition has been called *mucous fermentation;* it very remarkably illustrates the extremely different kinds of decomposition of one

and the same organic substance, according to the temperature at which the decomposition takes place. At a temperature of from 50° F. (10° C.) to 68° F. (20° C.) the beet-juice entered into vinous fermentation, and its sugar was resolved into carbonic acid and alcohol; at a higher temperature it likewise ferments, but in this case the sugar is converted into carbonic acid, lactic acid, gum, and some other products.

The sugar contained in many vegetable substances likewise undergoes a similar change, when these are mixed with salt, and kept for some time in a compressed state. The acid taste which we perceive in sour-krout, &c., is owing principally to *lactic acid*, which is formed in these substances in a way not yet thoroughly investigated.

But beside this acid, we frequently find in the above-mentioned sour substances another, called *butyric acid*, which imparts to them their peculiar odour. This acid, it seems, may also be produced by the metamorphosis of vegetable mucus, for it is always generated when vegetable mucilaginous substances—for instance, althæa-root, quince-seeds, linseed, &c.—are allowed to remain for some time in water.

FORMATION OF ALCOHOL, ACETIC ACID, AND LACTIC ACID, IN MAKING BREAD.

516. *Flour.*—The seeds of the various kinds of corn which we use in the preparation of flour and bread contain, as principal constituents, *starch* and *gluten*, and also a little sugar. On grinding the corn, the husks, and the parts contiguous to them, which are rich in oily matter (nitrogen and phosphate of lime), separate, constituting the *bran*, and there is left from the inner whiter mass, called the albuminous substance, the *flour*. The gluten is tougher, and more difficult to grind than the starch; this explains why the finer *white flour*, obtained by repeated sifting (bolting), is *richer in starch*, while the coarser and *darker flour* is *richer in gluten*. The nutritive property of flour is to be ascribed to the azotised gluten; unbolted flour, and bread made of it, are accordingly more nutritive than white flour and white bread, but at the same time less digestible (soluble).

Experiment.—Mix some flour with lukewarm water to a thick paste, cover it with a board, and let it remain for eight or ten days in a warm place. The paste is gradually altered, and two distinct periods may be observed during the change. In the first place, on the third or fourth day bubbles of air are evolved from it, having a sour, unpleasant smell, and the dough now possesses the capacity of converting sugar into *lactic acid*, as may be readily perceived by adding a little of it to some sugared water, and letting it stand in a warm place. After six or eight days the dough acquires a pleasant smell, and it now acts, when added to a solution of sugar, like yeast; that is, it effects a decomposition of the sugar into *alcohol and carbonic acid*. If the dough is allowed to stand still longer, it again acquires an acid taste, but which now proceeds from the *acetic acid* into which the alcohol previously generated gradually passes over *(leaven)*. In this state it also excites a spirituous fermentation in sugared water; but this spirituous fermentation immediately passes over into the acid—into *the formation of vinegar*. It is obvious, from what has previously been stated, that the different actions of the flour, when in a state of decomposition, upon the sugar, depend upon the albuminous matter, the gluten, contained in the flour; consequently, we might call the slightly altered gluten a lactic acid ferment, that which is more altered an alcohol ferment, and that which is still further altered a vinegar ferment.

517. *Bread.*—What thus takes place slowly proceeds rapidly in the making of bread, since a ferment is purposely added to the flour, which has been stirred up with water.

In the making of white bread, the surface-yeast of beer is used as a ferment; this, as is known, is the most powerful alcohol ferment. The sugar contained in the flour is thereby resolved into alcohol and carbonic acid, which struggle to escape, whereby the tough mass of dough is disintegrated, and rendered light and porous *(rising of the dough)*. These substances, together with about half the water employed, volatilise by the rapid heating in an oven, having a temperature of from 320° F. (160° C.) to 356° F. (180° C.), and the cellular partitions of the baked bread acquire such solidity, that they retain their form and place even after cooling. But if the heat of the oven is not sufficient, or the dough is too watery, then the partitions harden too slowly, and, on the escape of the carbonic acid, collapse, or run into each other *(slack baking)*. This happens most frequently with dark bread, since, in consequence of its greater amount of gluten, it retains the water more obstinately, and accordingly dries and hardens more slowly than white bread, in which the starch is more abundant.

Leaven is commonly used as a ferment in the preparation of black bread. There is formed, during the process, besides alcohol and carbonic acid, a little acetic and lactic acids (perhaps also some butyric acid), which communicate to the bread an acid taste. From three pounds of flour we obtain about four pounds of bread; consequently, a quarter of the bread consists of fixed water. The light, porous bread dissolves easily in the stomach; we say that it is easily digestible, and that the compact heavy bread is difficultly digestible.

518. It is known (§ 458) that starch is converted, by roasting, into *gum* (dextrine); a part of the starch undergoes, also, this change in the oven, particularly on the surface of the baked bread, which receives the strongest heat from the roof of the oven. If the crust of the hot bread is rubbed over with water, and the bread is then replaced for a few minutes in the oven, some of the dextrine is dissolved, and forms, after the evaporation of the water, the shining coating which we see on loaves of bread and rolls.

519. Carbonic acid, as applied to the rising of bread, may be more or less advantageously generated in other ways than by the fermentation of sugar; indeed, entirely different substances, which become aeriform on the application of heat, may be used for the purpose.

Experiment.—Mix intimately together two grains of finely pulverised *bicarbonate of soda*, and a drachm and a half of flour, and knead the mixture into a dough with one drachm of water, to which four drops of common muriatic acid have previously been added. Let the dough remain for some time in a warm place, and then bake it on the hot flue of a stove, or in a spoon over an alcohol lamp. A porous mass of bread is obtained, because the carbonic acid of the soda salt is expelled by the muriatic acid, and raises the dough while it is still soft. The common salt which is formed remains behind in the bread, and imparts to it a saline taste. This method has been introduced in many places for making bread, cakes, &c., on a large scale.

Experiment.—Rub a drachm and a half of flour with a few grains of *carbonate of ammonia*, and then knead it with a drachm of lukewarm water into a dough, and treat it as in the last experiment. In this case, also, the mass will become light and porous after the rising and baking, because the carbonate of ammonia (salt of hartshorn) is rendered aeriform by the heat, and during its escape the particles of the dough are forced asunder. In this way the bakers usually prepare their light and spongy cakes, as, for instance, gingerbread, &c. *Alcohol* and *rum*, which are sometimes kneaded with dough to promote the rising, act in a similar way.

RETROSPECT OF THE CHANGES OF SUGAR AND ALCOHOL.

1. *Sugar* is converted—

a.) By the loss of oxygen and hydrogen, into water and brown substances rich in carbon.

b.) By the addition of oxygen, into saccharic acid, oxalic acid, and water, and finally into carbonic acid and water.

c.) By contact with nitrogenous substances at a low temperature, into (rich in hydrogen) alcohol and (rich in oxygen) carbonic acid (vinous fermentation).

d.) By contact with nitrogenous substances at a somewhat higher temperature, into lactic acid, mannite, and many other substances (mucous fermentation).

2. By the changes mentioned under *c* and *d*, the nitrogenous substance is also simultaneously transformed into new compounds (yeast, ammoniacal salts, &c.).

3. The conversion of the sugar into alcohol and carbonic acid, and that of the nitrogenous substance into yeast, take place at a low temperature slowly (bottom fermentation), at a higher temperature rapidly (surface fermentation).

4. Hitherto alcohol has been prepared only by this method—namely, by the fermentation of sugar.

5. Starch is indeed used for the manufacture of alcohol, but it must always be previously converted into sugar.

6. *Alcohol* is converted,—

a.) By the loss of all its oxygen and hydrogen, into elayle (olefiant gas) and water.

b.) By the loss of some oxygen and hydrogen, into oxide of ethyle (ether) and water; this oxide of ethyle can combine as a base with acids (compound ethers).

c.) By the addition of oxygen, into aldehyde and water, and by still more oxygen, into acetic and other acids. If we follow the process of oxidation, as it proceeds, we shall observe the following order of changes:

From alcohol and oxygen are formed aldehyde and water;
" aldehyde and oxygen " " acetic acid;
" acetic acid and oxygen " " formic acid and water;
" formic acid and oxygen " " oxalic acid and water;
" oxalic acid and oxygen " " carbonic acid.

7. The last products of this process of oxidation are consequently those into which the alcohol passes when it burns—namely, carbonic acid and water.

8. Sugar belongs to the organic compounds rich in carbon, alcohol to those rich in hydrogen, acetic and the other acids to those rich in oxygen.

IX. FATS AND FAT OILS.

520. *Experiment.*—Break open an almond, and squeeze the white meat together by means of the finger-nail; small drops of fluid will be expressed, which are slippery to the touch, and render blotting-paper greasy and transparent. This liquid is called *oil of almonds.* If the almonds are first pounded, and then subjected in a cloth to strong pressure, we shall obtain more than one-fourth of their weight of oil of almonds. A great many plants contain a similar oily juice, especially in their seeds, and from many of the latter, oils are obtained by pounding and expressing. The term *fat oils* has been given to this kind of oils, because they are unctuous to the touch, and thick flowing. They occur in small quantity in almost all plants, even in those where we should not expect to find any; for instance, in different kinds of corn, grasses, &c.

521. *Experiment.*—Boil some fat pork cut up into small pieces for some time in a little water, and while the soft mass is still hot, press it in a linen cloth; a fat oil will float on the surface, but it is fluid only at a temperature of about 86° F. (30° C.); below this temperature it congeals into a solid, yet soft, white substance. This is also lubricating to the touch, and produces greasy spots on paper. Those kinds of fat, which, at the common temperature, have a *soft* unctuous consistency, are called *lard,* or, improperly, *fat;* and the cellular membrane and skin remaining in the cloth, and saturated with fat, are called *scraps.*

522. The suet of mutton, when treated in the same way,

yields a fat which, when hot, is also fluid, like oil, but which, when cooled only to about 9° F. (36° C.), congeals, and then forms *tallow*, a still *harder* substance than lard. By boiling and roasting, we can melt out fat from all animal substances, especially from those of the domestic animals, in which we are able to produce a great quantity of fat by keeping them confined, and giving them a plentiful supply of food. The fats obtained by boiling with water are white, as thereby they do not become heated above 212° F. (100° C.); while those obtained by roasting have a yellow or brown colour (brown butter, gravy of roast meat, &c.), because in this case a portion of the fat becomes burnt by being subjected to a stronger heat,—to a heat, perhaps, even above 572° F. (300° C.) In a strict sense, animal fats belong to the last division of this work, but they agree in their properties so exactly with the vegetable fats, that the subject will be rendered more intelligible by considering them together under the same head.

The fats of plants are mostly liquid (fat oils), those of the carnivorous mammalia and of birds are soft (lard), and those of the ruminating mammalia hard (tallow).

PROPERTIES OF FATS.

523. *Experiment.*—Rub a little fat upon paper, and place it upon a hot stove; the grease-spot will not disappear, however long the paper may be heated, since *the fats are not volatile.*

Fats not only spread with great ease on paper, but also on all other porous substances; as, for instance, on wood, leather, &c. Since the fats remain soft for a long time in the interior of these substances, we possess in them means for rendering flexible substances supple, and of maintaining them in this state. For this reason, leather harness and shoes are greased from time to time; and for the same reason, also, the leather-dresser impregnates his sheep-skins with fish oil in the fulling-mill, to give them greater softness and pliability when they are worked up into gloves, &c. That clay and loam have a great power of absorbing fat is obvious, as these substances are able to draw out again the grease that has soaked into wood or paper. Thin substances acquire a greater transparency when their pores are filled with fat instead of air; common paper is rendered in this way so transparent, that it may be used for tracing and for transparencies.

524. The fats *float upon water;* they have accordingly a less specific weight than water. On account of this property, they may be used for excluding air from other bodies. A solution of green vitriol speedily attracts oxygen from the air, and deposits brown hydrated sesquioxide of iron (§ 285); but it remains unchanged when it is covered with an oily film. Freshly expressed lemon-juice soon moulds in the air; it does not mould under a covering of oil. Preserved fruits keep much longer when melted butter is poured over them.

Fats are *insoluble in water;* hence they may be used for protecting other bodies from being penetrated by water. By greasing with tallow or fat, we render our shoe-leather impervious to moisture; by oiling, we prevent the rusting of iron in damp air; and by a coating of linseed oil, or linseed-oil varnish, we guard against the penetration of dampness into wood, sails, cordage, and their consequent rapid moulding and rotting. Timber saturated with oil remains, as has been shown by late experiments, unchanged in moist earth, while common wood is frequently destroyed by putrefaction, in the course even of a few years.

525. *Emulsion.—Experiment.*—Shake some oil and water briskly together in a test-tube; the oil divides into small drops, and renders the water milky; but on quietly standing it soon rises again to the surface. It is kept in suspension in the water much longer when some mucilaginous substances, such as gum or albumen, are contained in the water; as may be seen by triturating some oil with albumen, yolk of eggs, or a thick solution of gum Arabic, and afterwards gradually adding water. The milky fluid thus obtained is called an *emulsion* (*oleaginous emulsion*), and the oil in it will not separate from the water till after some days.

Experiment.—A second mode of preparing emulsions consists in bruising seed rich in oil, such as almonds, or rape-seed, in a mortar, and gradually adding water. In all these seeds mucilaginous and albuminous substances are present, which are dissolved by water, and effect a fine division of the oil.

We have a natural emulsion in the *milk* of the mammalia. Cow's milk is turbid, because the butter floats about in it in small globules, invisible to the naked eye; these globules of fat are kept suspended in the water because a body similar to albumen—the caseine—is dissolved in the milk. On longer standing, the caseine becomes insoluble (it coagulates), and the lighter butter collects, as cream, upon the surface of the milk.

526. *Drying Oils and Unctuous Oils.—Experiment.*—Rub upon a copper coin a drop of linseed oil, upon another a drop of olive oil, and let them both remain for several days in a warm place; the linseed oil will dry up into a resinous *solid* mass, while the olive oil will remain *greasy*. All oils absorb oxygen from the air, and become thereby thicker, and also acquire a disagreeable smell and taste (rancidity); but there is an essential difference between them, as many oils become perfectly hard and dry, while others, on the contrary, remain soft and sticky. Accordingly, oils are divided into two classes, into *drying* and *unctuous oils*. The former may also be called varnish oils, as they are particularly adapted for varnishing. The latter are called unctuous oils, because, when it is desired to prevent, by means of grease, the friction and heating of solid bodies, these oils remain soft and unctuous much longer than the drying oils.

527. By the absorption and condensation of oxygen taking place on the drying of oils, heat must be liberated, as in every condensation of an aeriform body to a liquid condition. Under some circumstances, as when freshly oiled or varnished substances, such as wool, linen, &c., are heaped together in large masses, this heat rises to such a degree, that *spontaneous combustion* occurs; therefore it is not prudent to lay such articles too closely upon each other, before they have become thoroughly dry.

CHANGES OF FAT BY HEAT.

528. *Experiment.*—Heat some linseed oil over an alcohol flame, and test the temperature of it occasionally by a thermometer. At first the heat rapidly rises to 212° F. (100° C.), and remains for some time at that temperature, during which time the oil boils moderately; this behaviour is occasioned by all crude oil containing watery particles, which evaporate at 212° F. (100° C.) As soon as these have volatilised, the temperature is suddenly elevated even above 572° F. (300° C.), when the oil begins to boil for the second time,

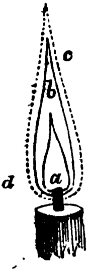
Fig. 203.

but emitting now a white smoke having a very disagreeable odour. This vapour consists of decomposed oil, principally of illuminating gas, and burns, when kindled, with a brisk flame; fats are accordingly *combustible*, but only at a temperature sufficiently high to effect their chemical decomposition.

Illuminating gas is frequently prepared on a large scale from oils, by causing them to drop upon a red-hot iron vessel, from which the gas generated (*oil gas*) is conducted by a pipe into a receiver (*gasometer*).

529. Every lamp, every candle, is an illuminating-gas apparatus on a small scale. But in this case the combustion takes place only with the aid of an easily combustible body, the wick. When a fresh candle is lighted, the cotton of the wick first inflames, and the heat thus produced is sufficient to melt the tallow in contact with the wick. The melted tallow now ascends by capillary attraction (§ 106), through channels formed by the fibres of the cotton lying beside each other, and in these channels it becomes heated by the flame to a temperature of above 572° F. (300° C.), and consequently is decomposed into illuminating gas. Whale oil, rape-seed oil, oil of colza, olive oil, tallow, and wax, are most frequently used as *illuminating materials*.

Fig. 204.



530. *Experiment.*—Let some drops of water fall from a shaving, that has been dipped in water, into some oil burning in a spoon; the oil spatters about, because the heavier water sinks in it and is suddenly converted into vapour, which ejects the oil. Burning fat, such as varnish, lard, &c., should therefore never be quenched with water; but the quenching may be done easily and without danger, if the vessel is covered with a board or a piece of sheet iron, thus excluding the air, which is requisite for the continuation of the combustion.

531. As in wood (§ 120), so also in fats, the hydrogen burns more quickly than the carbon, and this is the reason why the partly burnt oil remaining after the extinction is richer in carbon, and has a darker colour. An *empyreumatic oil* of this kind is kept in the shops, under the name of the *oil of bricks*, or *philosophic oil*. On still further heating, the linseed oil becomes continually blacker, and at the same time thicker, so that it finally acquires a viscid consistency (factitious birdlime), and

when mixed with soot forms the basis of the important *printing-ink.*

COMPOSITION OF FATS.

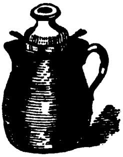
532. The similarity in the combustion of fats and wood indicates that they have a similar constitution. Indeed, both bodies possess the same constituents, namely, carbon, hydrogen, and oxygen; the difference depends only upon the quantity; the fats contain, namely, more hydrogen and less oxygen than wood. They accordingly belong to one and the same category with alcohol and ether,—to that of the *organic bodies which are rich in hydrogen.*

533. *Stearine and Oleine.*—We cannot, however, regard fats, like woody fibre or alcohol, as homogeneous bodies, but as *mixtures of several more simple kinds of fat,* into which the fats, without being chemically decomposed, may be separated.

Experiment.—If, during the winter, you place a vessel containing lamp oil in the cold, part of it will congeal into a solid mass, like tallow, while the other part remains fluid; the oil is accordingly separated by the cold into two fats, one solid and one fluid. The solid fat has received the name of *stearine,* and the fluid that of *oleine.* By repeated cooling, the greater part of the stearine may be separated from the oil. The stearine obtained is pressed between blotting-paper as long as the paper absorbs any liquid oil (oleine).

Experiment.—Twist a wire round a wide-mouthed phial, in such a manner as to form two handles, by means of which the phial may be suspended in a jar, which is then half filled with water, and heated upon a tripod. Put into the phial one drachm of tallow and enough strong alcohol—absolute alcohol is the best—to fill it three-quarters full. When the contents of the phial boil, remove the lamp, and leave the phial in the water-bath, till the melted tallow has again settled at the bottom, and then pour the hot supernatant alcohol into a beaker-glass. Repeat the boiling three or four times, with fresh alcohol. Let the alcohol stand for some hours in cold water, covered over; afterwards filter the liquid from the granular powder that has separated, wash the powder several times with cold alcohol, and dry it in an airy place. This mass, which, when dry, is laminated

Fig. 205.



and slightly lustrous, is the *stearine* of mutton-tallow; the *oleine* must be sought for in the filtered alcohol. It remains behind, in the form of a somewhat thick oil, when the alcohol is allowed to evaporate in a cup on a warm stove.

As is obvious from these experiments, *stearine and oleine form the approximate constituents* of fat, and this is the reason why some fats are hard, some soft, and others liquid; the solid stearine predominates in the former, the fluid oleine in the latter. Pure stearine begins to melt at 140° F. (60° C.), pure oleine begins to solidify only at a very low temperature. One pound of mutton contains about three-quarters of a pound of stearine; one pound of olive oil barely a quarter of a pound.

The following are among the most important fats:

A. VEGETABLE FATS.

a. Drying Oils (Varnish Oils).

534. *Linseed Oil.*—The well-known linseed yields, on being subjected to pressure, a yellow oil, equal to one-fifth of its own weight, which is gradually bleached by long exposure to the sunlight. It is most frequently used in oil varnishes.

Experiment.—Add to an ounce of linseed oil a quarter of a drachm of litharge, and half a drachm of acetate of lead; put the mixture in a warm place, and frequently shake it. The liquid, clarified by settling, now dries much quicker than it would have done before; it is the common *linseed oil varnish*, which, mixed with colours, is generally used for imparting a gloss to wood, metal, &c. The so-called oil-cloth is cotton cloth smeared with coloured varnish; oil-silk is varnished silk. This varnish is commonly prepared, on a large scale, by heating one hundred pounds of linseed oil with one pound of litharge, and maintaining the mixture for an hour at a temperature of 212° F. (100° C.) A stronger heat renders the varnish darker and thicker, and, besides, might easily cause it to boil over and take fire. The slimy, dingy white sediment which remains after both processes is a combination of mucilaginous substances with oxide of lead. All oils contain, in the unpurified state, mucilaginous (gummy and albuminous) substances, which retard the drying; these are rendered insoluble by oxide of lead. Varnish is, accordingly, linseed oil free from mucilage.

By kneading together linseed-oil varnish and chalk, we obtain a plastic dough, common putty.

Hemp oil, from hemp-seed, of a yellowish-green colour, is also used in the preparation of varnish, and likewise for burning, and for the manufacture of green soap.

Poppy oil, from poppy-seeds, serves as a table oil, and for the preparation of a very clear varnish.

Castor oil, from the seeds of the castor-oil plant, is a purgative medicine.

Oil is also obtained from pumpkin-seeds, walnuts, sunflower-seeds, &c.

b. Unctuous Oils (*remaining viscous*).

535. *An oil for burning* is expressed from rape-seed. In order that it may burn without depositing soot on the wick, it must be refined, that is, purified from its mucilaginous parts. This is done, not by oxide of lead, but by sulphuric acid.

Experiment.—Mix one ounce of crude rape oil with eight drops of common sulphuric acid, and shake it frequently; in half an hour add half an ounce of water, again shake the mixture briskly, and set it aside for some days, when the oil floating on the surface will be freed from mucilage (purified). The slimy parts, charred by the sulphuric acid, and rendered insoluble, are found settled in the water at the bottom of the vessel. The sulphuric acid still adhering to the oil is removed by repeated washing with water. Sulphuric acid chars, as is known, all organic substances (§ 173), some (for instance, mucilage) easily, others (for instance, oil) with difficulty; if just enough sulphuric acid, therefore, is added to the oil to char the mucilage, then the mucilage only is destroyed, and the oil remains undecomposed. A larger quantity of sulphuric acid would also attack the oil.

Olive oil is pressed out from the pulp of olives, the fruit of the olive-tree. The finest cold-pressed *Provence oil* is of a bright yellow colour, the hot-pressed common olive oil is greenish; these two sorts are, as is well known, universally used as a table condiment, and for greasing machinery. There is a thicker, darker kind, of an inferior quality, which is used in France and Italy for the manufacture of the so-called Naples or Marseilles soap.

Oil of almonds is obtained by subjecting sweet almonds to pressure. Bitter almonds also yield by cold pressure a good oil of almonds, while by hot pressure an oil is obtained containing prussic acid.

Oils are obtained also from hazel-nuts, beech-nuts, plum and cherry stones, apple-seeds, &c.

Cocoa-nut oil, from the kernel of the cocoa-nut, is, at average temperatures, as soft as hog's lard; it has a white colour and a somewhat disagreeable smell.

Palm oil, a yellow fat, similar to butter, likewise proceeds from the fruit of a species of palm-tree. Its yellow colouring matter is removed when heated to 266° F. (130° C.) (bleaching by heat).

Cocoa-nut oil and palm-oil are now manufactured into soap in very large quantities.

The following kinds of fat are employed in pharmacy:

Cacao butter, the tallow-like white or yellowish fat of the cacao-nut, the cause of the fat particles which rise on boiled chocolate.

Oil of nutmegs, the yellow, agreeably-smelling fat of the nutmeg, having the consistency of butter.

Oil of bay, the beautifully green, suet-like fat of the berries of the bay-tree.

B. ANIMAL FATS.

536. Our common domestic animals, cows, goats, and sheep, supply us with several kinds of fat;—a harder, white kind (*tallow* or *suet*), which is deposited in and covers the flesh; a softer kind, generally of a yellow colour, which separates from their milk (butter); and, besides these, there are the fats of the marrow and the hoofs.

The fat of the stag is white and hard, like *mutton-suet*.

Hog's lard, *goose-grease*, &c., are well enough known. In earlier times, when it was believed that each single animal fat concealed within itself peculiar properties, innumerable kinds of these fats were kept in the apothecaries' shops; but now, plain hog's lard supplies the place of all the others.

537. *Train oil* is obtained by means of heat from the blubber of whales, dolphins, seals, and different fishes. When melted out at a moderate heat, it has a yellow colour, and a slight odour, which is not disagreeable; but that which is obtained by strong heat, or from fishes that have become putrid, is of a dark-brown colour, and has a very disagreeable odour. Fish oil is preferred for greasing leather; it is likewise used in dicine and in the preparation of soft soap.

538. *Spermaceti* is white, sparkling, and so hard that it may be rubbed into a powder, and is found enclosed in peculiar cavities in the head of the sperm-whale.

539. *Wax* (cera) occurs in small quantities in all plants, especially in the shining coating of the leaves, stalks, and fruits; for instance, in the skins of apples, and particularly in the pollen of flowers. Some plants of Japan and South America contain so much wax that it may be separated by boiling with water and by pressure, and it is then introduced into commerce under the name of *vegetable* or *Japan* wax. But the purveyors of our common wax are the bees, which gather it from the flowers, and use it in building their cells. These insects may, perhaps, make their wax in part also from the sweet juices of the plants on which they feed, for accurate experiments have proved that bees have the capacity of exuding from their abdominal rings the sugar upon which they feed, converted into wax. The yellow wax is bleached by cutting it into shavings, exposing them to the sun, and frequently watering them. Yellow wax melts at 143° F. (62° C.), white wax at 158° F. (70° C.) Wax is not only used for imparting stiffness to thread, and in the manufacture of candles, but, when dissolved in potash lye, it forms the so-called wax-soap, employed for giving a gloss to variegated paper and for polishing floors, and when mixed with oils is made into plasters and ointments (cerates). Paper immersed in hot wax forms a good material for covering vessels, to protect them from moisture. Turpentine is added to wax, in order to render it more pliant and tougher, as we find it in wax candles, and in the wax used for grafting trees.

FATS AND ALKALIES (SOAPS).

Fig. 206.

540. *Hard Soap.—Experiment.*—Make first a *strong lye* with one drachm of the caustic soda of commerce and one ounce of water, and next, a *weak lye*, with one drachm of caustic soda and two ounces of water. Boil the latter gently with an ounce and a half of beef-suet, for half an hour, in a vessel only half filled with the mixture, and then add the strong lye gradually while the boiling continues. The fat and lye gradually unite and form a uniform mass, of a gluey consistency, which after a time becomes thick and frothy. If a drop of this, when

pressed between the fingers, presents firm white flakes, then add half an ounce of common salt, boil for some minutes, and let the whole mass quietly cool. We obtain a firm mass (*soap*) and a watery liquid, in which the common salt and some free soda remain dissolved (*under-lye*). If the soap, when boiled with water, forms a turbid solution, it still contains some unsaponified tallow, in which case add to it some weak lye, and continue boiling until the sample gives a clear solution in water; add again some common salt, and let it cool. The soap prepared in this manner has the same composition as common *house-soap*. More recently, palm oil or cocoa-nut oil has been used partly or entirely to supply the place of tallow, the palm oil because it is cheaper than tallow, and the cocoa-nut oil because it communicates to the soap the property of forming a very strong lather.

Experiment.—Repeat the former experiment, using olive oil instead of tallow; hard soap is likewise obtained (*oil-* or *Marseilles soap*).

541. *Soft Soap.*—*Experiment.*—Prepare again some oil-soap, as above described, but instead of soda use potassa lye, which is prepared from caustic potassa and water, and omit the addition of common salt; the glutinous mass does not then pass by boiling into a hard soap, but, after sufficient evaporation of the water, yields a soft mass (*soft soap* or *potassa soap*). This kind of soap is frequently employed in print works for the cleansing of coloured fabrics. If train oil, hemp-seed oil, or linseed oil is used instead of olive oil, a darker-coloured soft soap is obtained, which is usually coloured green by indigo and turmeric (*green and black soap*).

Ammonia acts far more feebly than potassa and soda upon fats. If some of the unctuous oils are shaken up with ammonia, thick white mixtures, *liniments*, are obtained, which are often applied by friction to the skin.

Hard soaps are formed from fats by *soda*, *soft* soaps by *potassa*. The chemical process taking place in both cases may be explained as follows.

542. *Fatty Acids.*—The fats, as was shown in § 533, consist of several simple, sometimes solid, sometimes fluid, kinds of fat,—among which the solid stearine and the fluid oleine are especially predominant. These proximate constituents of the natural fats may be regarded as saline bodies; that is, as com-

binations of an acid with a base. Every simple fat contains a peculiar acid,—stearine, stearic acid; oleine, oleic acid; palmitine, palmitic acid, &c.; but all contain one and the same base, to which the name *oxide of glyceryle* (sweet principle of oil) has been given.

Stearine	is, accordingly,	stearate of oxide of glyceryle.
Oleine	" "	oleate of oxide of glyceryle.
Tallow	" "	a mixture of much stearate, and a little oleate of oxide of glyceryle, &c.

To designate the different acids contained in the fats, the general term "fatty acids" will always be used in the following pages. *Fats in general are, accordingly, to be regarded as combinations of fatty acids with oxide of glyceryle, or as salts of fatty acids and oxide of glyceryle.*

543. *The process of the formation of soap* is thus one of simple elective affinity; the stronger bases, soda and potassa, displace the weaker oxide of glyceryle, and combine with the fatty acids, forming compounds of fatty acids with soda (*soda soap*), or of fatty acids with potassa (*potassa soap*). From potassa and a fatty acid with oxide of glyceryle are formed a potash-salt of the fatty acid and free oxide of glyceryle (potassa soap). From soda and a fatty acid with oxide of glyceryle are formed a soda-salt of the fatty acid and free oxide of glyceryle (soda soap).

In the first two experiments the separated oxide of glyceryle, soluble in water, remains in the under-lye; but in the soft soap, when the surplus of water does not separate as a fluid from the soap, but is removed by evaporation, it remains mechanically mixed with the soap.

The action of common salt may be seen by trying to dissolve hard soap in salt water; no solution takes place, not even on boiling, *for soap is insoluble in salt water*, and likewise in strong lye; therefore soap may be precipitated from a solution in water by the addition of common salt. This method of separation is usually employed on the large scale, since it yields a purer soap than when the water is removed by evaporation; for, in the latter case, hydrated oxide of glyceryle, surplus of lye, and perhaps, also, some impurities contained in the lye or fat, remain mixed with the soap, while by the former method they are dissolved in the liquid (*under-lye*).

544. *Conversion of Potassa Soap into Soda Soap.—Experiment.*—Dissolve some of the soft soap obtained in § 541 in

boiling water, and sprinkle in some salt; the soap separates, and collects upon the surface of the water, yet, when cold, it will no longer be soft, but hard. The salt here acts in another manner; it occasions an interchange of the constituent parts—namely, from the potash-salt of the fatty acid and chloride of sodium are formed chloride of potassium and the soda-salt of the fatty acid (soda soap).

Soap-makers often proceed in this way on a large scale; they make a caustic potassa lye of wood-ashes and lime (lye of wood-ashes), boil it with fat, and finally convert the soft potassa soap obtained into hard soda soap, by means of common salt.

SOAP AND ACIDS.

545. *Experiment.*—Dissolve some of the hard soda soap in hot water, and add to it vinegar by drops until a turbidness ensues. Vinegar, and other acids, are stronger than the fatty acids; therefore they withdraw from the latter the base, and the fatty acids are set free. As these are lighter than water, and at the same time insoluble in it, so they collect on the surface of the water. The fatty acids thus obtained resemble tallow externally, but it is evident that they are not tallow, since, even after long washing, they still have an acid reaction, which is not the case with tallow; and they are easily dissolved in hot alcohol, but tallow very difficultly. Three-fourths of the mass consist of stearic acid, one-fourth of oleic acid. When strongly pressed between blotting-paper, the oleic acid soaks into the paper, and the stearic acid remains behind.

Stearic acid is harder and more brittle than wax, brilliantly white, translucent, and melts at the temperature of 158° F. (70° C.) There are now large factories for the preparation of it, and it is used in the manufacture of the stearine candles, which have become so popular.

Experiment.—Heat some ounces of strong alcohol in a water-bath, and when it boils add to it as much stearic acid as will dissolve in it. Pour half of the solution obtained into cold water, and let the other cool quietly; in the former case the stearic acid is obtained as a light, silky, brilliant mass, while in the latter it takes the form of delicate crystalline plates.

Fig. 207.

546. *Experiment.*—If an acid is added to a

solution of oil-soap, an oily fluid separates, which consists principally of oleic acid.

Oleic acid, in its external appearance, is hardly to be distinguished from olive oil, but it differs from it in the following respects: it has an acid taste and reaction, which olive oil has not, and it readily dissolves even in cold alcohol, which olive oil does not. The oleic acid, procured in stearic-acid factories from tallow, as a secondary product, now frequently occurs in commerce, and, on account of its cheapness, is employed in the manufacture of soap, and in greasing wool for spinning.

547. *Oxide of glyceryle* (glycerine, or sweet principle of oil).—*Experiment.*—Add to the soft soap, prepared according to § 541, a solution of tartaric acid; and leave the watery fluid, after being clarified by filtration, to evaporate in a warm place. The saline mass remaining after evaporation consists of bitartrate of potassa (tartar) and of the base of the fats, oxide of glyceryle; when strong alcohol is added, the latter dissolves, while the bitartrate of potassa, together with any excess of tartaric acid that may be present, remains undissolved.

The oxide of glyceryle, which remains after the evaporation of the alcohol, has the appearance of a yellow syrup. It has not an alkaline taste, but is sweet, like sugar; neither does it react basically, although it is soluble in water. It has, accordingly, no similarity to other bases soluble in water, as, for example, potassa or soda. But the reason why it is regarded as a base is evident from its behaviour with acids; it is considered as a base, because it combines with acids in fixed proportions, forming compounds having the character of salts. It constitutes only about a tenth or twelfth part of fats; an ounce and a quarter of it, at most, is contained in one pound of tallow.

Experiment.—Wipe the basin containing the small quantity of the oxide of glyceryle that has been obtained, with white blotting-paper, and heat the latter in a spoon. During the combustion there will be evolved from it an extremely pungent odour, proceeding from the oxide of glyceryle, which is decomposed by the heat into a volatile, extremely pungent substance (*acroleine*, or *oxide of acryle*), which produces tears. Hence is explained the pungent odour which is perceived during the imperfect combustion of all kinds of fat. This odour is very strikingly manifested, also, when varnished articles are drying —for instance, in the drying-chambers of the oil-cloth factories.

This volatile matter may be formed also, even at a low temperature, from glycerine. No smell of acroleine is evolved on heating the pure fatty acids.

PROPERTIES OF SOAPS.

548. *Washing with Soaps.*—Soaps have two important properties;—1st, they dissolve fat and oils; 2nd, they are very easily resolved, merely by mixing with much water, into an acid salt and free alkali; the latter dissolves, as is well known, most organic substances, but the former effects by its lubricity an easy washing away of the dissolved matter from other substances. On these two properties depends the application of soap in washing. The separated acid salt of the fatty acids with alkali both diminishes the action of the free alkali, and keeps the articles pliant which are washed with soap, while they would become rigid if they were cleansed with caustic alkalies alone. To prevent the shrinking of woollen articles, wash them with a weak solution of carbonate of soda, instead of with soap.

549. *Soap and Alcohol.*—*Experiment.*—Pour one ounce of alcohol upon one ounce of the shavings of tallow soap; the soap is completely dissolved on heating in the water-bath, but the solution congeals on cooling to a transparent *jelly*. This jelly-like soap, mixed with camphor and ammonia, is called *opodeldoc*. The white stars separating from this consist of crystallised stearate of soda. All soaps prepared from solid fats (rich in stearine) behave like tallow soap.

Experiment.—Dissolve one drachm of Naples soap in half an ounce of alcohol; this solution does *not* coagulate on cooling; it forms the *tincture of soap*. By evaporation, a diaphanous soap is obtained (*transparent soap*). All the soaps made from the fluid fats (rich in oleine) act like the Naples soap.

550. *Insoluble Soaps.*—*Experiment.*—If some lime-water is added to a solution of soap in water, a precipitate of insoluble lime soap is formed; hence is explained why spring-water, which generally contains lime (hard water), neither dissolves soap nor lathers with it, and accordingly cannot be used for washing.

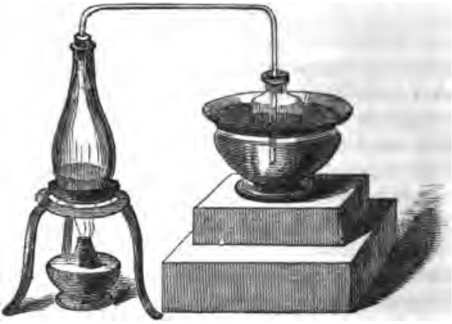
Experiment.—By adding acetate of lead (§ 337) to a solution of Naples soap in hot water, as long as a precipitate is formed, we obtain, by double elective affinity, acetate of soda, which remains dissolved, and a compound of fatty acid with oxide of lead, which separates as a white, adhesive mass, that may be kneaded with the moist hands, and formed into rolls (*lead soap* or *lead plaster*). From the compound of the fatty acid with soda, and the acetate of lead, are formed a compound of the fatty acid with oxide of lead (lead plaster) and acetate of soda.

In pharmaceutic laboratories, this plaster, generally known under the name of *diachylon*, is prepared in a different manner, namely, by boiling litharge with olive oil and some water. By this method oxide of glyceryle is readily obtained, and in larger quantities, as a secondary product; the plaster made has only to be washed with hot water, and the water evaporated after the oxide of lead dissolved in it has been previously precipitated by sulphuretted hydrogen. If, instead of litharge, white lead (carbonate of lead) is boiled with oil and water, we likewise obtain a compound of fatty acid and oxide of lead, since the carbonic acid is expelled by the fatty acids. In this manner the *plaster of carbonate of lead* is prepared, which has commonly a whiter colour than the former plaster, because it still contains some white lead mechanically mixed with it.

X. VOLATILE OR ETHEREAL OILS.

551. *Preparation of Volatile Oils.—Experiment.*—Put one ounce of turpentine in a dish in a warm place, and when it has become liquid transfer it to a capacious flask; pour upon it four

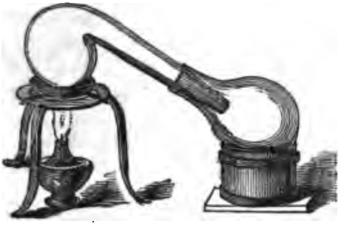
Fig. 208.



ounces of water, and distil until about three-fourths of the water have passed over. Pour the residue, while still hot, into cold water, in which the non-volatile portion of the turpentine remaining behind congeals to a solid mass (*resin*). A strong-smelling, colourless liquid, a volatile oil, commonly known under the name of *oil of turpentine*, floats on the surface of the water distilled over. Turpentine, a juice which exudes from pines, larches, and other trees, when the inner bark is cut through, is accordingly a mixture of resin and oil of turpentine; the latter is converted by heat, simultaneously with the water, into steam, and on cooling is again condensed to a liquid.

Experiment.—Distil in the same manner half an ounce of cumin-seeds (which have been previously bruised in a mortar), in a retort containing four ounces of water, until two ounces of water have passed over. The drops floating upon the water are likewise a volatile oil, *oil of cumin*; they have the smell and taste of the cumin-seeds, but in a stronger degree, while the residue remaining in the retort has scarcely the least smell or taste of them. All volatile oils possess a burning taste, and are somewhat rough to the touch; but the fat oils have a mild taste and an unctuous feel.

Fig. 209.



DIFFERENT KINDS OF VOLATILE OILS.

552. Whenever we perceive an odour in a plant, we may presume that a volatile oil is present, which gradually evaporates. But how incredibly diffused and diluted this must be in many plants, may be inferred from the fact that scarcely a quarter of an ounce of volatile oil is contained in one hundred pounds of fresh roses, or orange-flowers. We most frequently find the volatile oils in the flowers and seeds, sometimes in the stalks and leaves, but more rarely in the roots. They are obtained almost in the same way, without exception, as oil of turpentine, by distilling the vegetable parts with water. The oils procured from the peel of certain fruits, as the lemon,

citron, bergamot-pear, &c., form an exception, since such oils are obtained by expression from the fresh rind.

553. Of the most known volatile oils we obtain,—

a.) *From the flower:*

Oil of roses, a yellowish, thick fluid, with flakes resembling tallow floating in it.

Oil of orange-flowers (ol. neroli), colourless; becomes reddish on exposure to the light; contains no oxygen.

Oil of chamomile, a dark blue, thick liquid; becomes green, and finally brown, by age and light.

Oil of lavender, a yellowish, thin liquid.

Oil of cloves, yellowish, soon becomes brown; a somewhat thick fluid, heavier than water.

b.) *From seeds and fruits:*

Oil of cumin, colourless; becomes yellowish, and finally brown, by age.

Oil of anise-seed, yellowish; congeals even at 54° F. (12° C.)

Oil of fennel, colourless or yellowish; congeals likewise readily.

Oil of dill, yellow; becomes brown in the light.

Oil of nutmeg, a pale yellow, thin liquid, has the smell of nutmegs.

Oil of bitter almonds, yellow; heavier than water; contains prussic acid, and consequently is *very poisonous.*

Oil of mustard, yellowish, of an extremely pungent smell, causing lachrymation; contains sulphur.

Oil of juniper, colourless; contains no oxygen.

Oil of savin, colourless, or yellowish; a thin fluid; contains no oxygen.

Oil of parsley, pale yellow; on being shaken with water, separates into a light volatile oil, and into a heavy, solid, crystalline oil.

Oil of lemons, from lemon-peel, contains no oxygen.

Oil of orange-peel likewise contains no oxygen.

Oil of bergamot, from the rind of the bergamot orange, a pale yellow, very thin liquid.

c.) *From the leaves and branches:*

Oil of peppermint, colourless or yellowish, a very thin liquid, now frequently imported from America.

Oil of balm, pale yellow, has an odour like that of lemons.

Oil of marjoram, yellowish or brownish.

Oil of thyme, when fresh, yellowish or greenish; when old, brownish-red.

Oil of sage, when fresh, yellowish or greenish; when old, brownish-red.

Oil of wormwood, dark green; soon becomes brown or yellow, and viscous in the light.

Oil of rosemary—colourless and very thin—is, next to the oil of turpentine, the cheapest volatile oil.

Cajeput oil, from the leaves of a tree growing in the Moluccas; the oil, when pure, is colourless; the crude oil is commonly green, and often contains camphor; it has a camphorated odour.

Oil of rue, pale yellow or greenish.

Oil of cinnamon, yellow; soon becomes brown in the air; heavier than water.

Oil of turpentine, the most common of the volatile oils, is contained in all our fir-trees, and exudes from them, mixed with resin, as turpentine. (§ 568.) When purified, it is colourless and thin, and has an agreeable, penetrating odour; it contains no oxygen. An ordinary sort, possessing a disagreeable empyreumatic odour, obtained in the preparation of pitch from pine resin, is *crude oil of turpentine*.

Camphor occurs in commerce as a solid white, crystalline, odoriferous mass, prepared by distillation with water, or by sublimation from the wood of the camphor-tree, growing in Japan and the East Indies.

d.) *From roots:*

Oil of acorus, yellow or brownish.

Oil of valerian, pale yellow or greenish; becomes rapidly brown and viscous on exposure to the air.

It is very remarkable, that we sometimes find several sorts of oil in one and the same plant. Thus, for example, we find in the orange-tree three different kinds of oil; one in the leaves, another in the blossom, and a third in the rind of the fruit.

554. *Ferment Oils.*—*Experiment.*—If water is poured on the centaury-plant (Erythræa centaurium), and it is left in a warm place until fermentation commences, a very penetrating odour is evolved from the leaves, which were previously scentless; the odour proceeds from a volatile oil, which is generated during the fermentation. In a similar manner, the fresh, scentless leaves of the tobacco-plant obtain the well-known nicotian

odour by the so-called sweating process. Oils of this kind, which may be generated by fermentation from many other inodorous plants, are called *ferment oils.*

In the distilleries there is evolved also, on the fermentation of potatoes and grain, a disagreeably-smelling oil (*fusel oil*), which partly distils over with the brandy or spirit, and imparts to these liquids the fusel taste and smell. On filtering through charcoal, it remains behind in the pores of the latter.

555. *Empyreumatic Oils.*—Finally, oily volatile substances are produced by the dry distillation of vegetable and animal matter; for instance, oil of wood-tar from wood, oil of coal-tar from pit-coal, animal oil from bones, oil of amber from amber, &c. They are all distinguished by an exceedingly disagreeable odour, and are mixtures of various volatile substances. They are called *empyreumatic oils.*

Rock oil, or *petroleum* (πέτρος, rock), is of a similar nature; it oozes out from the earth in many places in Asia, where it is formed in a manner as yet unknown to us. The red colour of the oil occurring in commerce is given to it by the addition of alkanet-root.

PROXIMATE CONSTITUENTS OF THE VOLATILE OILS.

556. All these oils are *volatile* at average temperatures, except camphor, which begins to melt at the temperature of 347° F. (175° C.); but below this temperature forms a white, solid, crystalline mass. If the volatile oils are cooled, there is frequently separated from them a beautifully crystallised, solid, white, camphor-like substance, which has been called *stearoptene,* in opposition to the liquid portions that remain, which are called *eleoptene.* Accordingly, the volatile oils, like the fats, consist of two proximate constituents, one of which may be obtained solid and crystallised, but the other only as a liquid. Many oils—for instance, the oils of rose and aniseseed—are so rich in stearoptene, that, when kept in cool cellars, they congeal into a nearly solid mass.

ELEMENTARY CONSTITUENTS OF THE VOLATILE OILS.

557. The volatile oils are divided into three classes, according to the elements of which they are composed:

a.) Into the *non-oxygenated* oils (having two elements);

these consist only of carbon and hydrogen (C, H), so that they may be regarded as condensed illuminating-gas. To this class belong rock-oil, and oils of turpentine, juniper, savin, lemons, &c.

b.) Into *oxygenated* oils (having three elements), which, beside *carbon* and *hydrogen*, contain also *oxygen* (C, H, O); most of the other volatile oils have this constitution.

c.) Into *sulphuretted* oils, which are composed of *carbon*, *hydrogen*, and *sulphur* (sometimes with and sometimes without *nitrogen*). The oils of this class are distinguished by a very pungent smell, causing lachrymation, and by a great acridity, raising blisters on the skin when brought in contact with it. The oils of mustard, horseradish, scurvy-grass, garlic, hops, &c., belong to this class.

Of these elements, hydrogen (as regards the number of atoms) commonly predominates; hence, the volatile oils are usually reckoned among the organic substances *rich in hydrogen.*

PROPERTIES OF THE VOLATILE OILS.

558. *Experiment.*—Pour a drop of some volatile oil upon a sheet of paper, and let it remain exposed to the air; the paper at first receives an apparent grease-spot, but this disappears after a time, because the oil gradually evaporates. The name *volatile* or *ethereal oil* thus explains itself; and the disappearance of camphor, on being exposed to the air, is owing to this volatileness.

If the oiled paper is placed upon a warm stove, evaporation takes place much more rapidly. Aromatic oils are employed in this way for perfuming apartments. Usually a quantity of flowers, woods, and barks, finely cut up, are moistened with the oil, and scattered as a *fumigating powder* upon the stove.

559. *Experiment.*—Heat a quarter of an ounce of oil of turpentine in a vessel to boiling. A thermometer introduced into the liquid will indicate a temperature of about 302° F. (150° C.); oil of turpentine accordingly requires half as much heat again for boiling as water. Other oils often boil with even more difficulty. The vapour may be inflamed by a taper, when it will burn with an intense sooty flame; it is easily extinguished by covering the vessel with a board, but *water must on no account be employed for extinguishing burning oils.* Then remove the oil from the fire; after it is cold, mix it with

some water, and again heat it; as long as any water is present, the temperature of the fluid will not rise above 212° F. (100° C.) The ascending vapour is a mixture of aeriform water and aeriform oil. The same thing occurs here as previously mentioned; the less volatile oil evaporates with the more easily volatile water. The oils remain unchanged at the boiling point of water, but at their own boiling point, from 284° F. (140° C.) to 392° F. (200° C.), they become not unfrequently somewhat empyreumatic; this is the reason why water is always added in the preparation of oils, and also in the redistillation of them (*rectification*).

560. *Experiment.*—Inflame some drops of oil of turpentine put upon a shaving, and also a piece of camphor laid upon water; both bodies will ignite, and burn with a highly luminous and sooty flame. The volatile oils are far more easily combustible than the fat oils, which in order to burn with a flame must be heated to 662° F. (350° C.) We have consequently in oil of turpentine a convenient means for speedily lighting oil-lamps; it being merely necessary to smear the wick with a few drops of it.

Experiment.—Pour a mixture of half an ounce of absolute alcohol with half a drachm of oil of turpentine into a spirit-lamp; the mixture gives, when lighted, a strongly illuminating, but no longer a sooty flame, since all the carbon of the oil of turpentine is converted by the heat of the burning alcohol, rich in hydrogen, into illuminating gas, and then into carbonic acid (and water). This mixture is now used in lamps constructed for the purpose, and which are so made that the liquid evaporates in them, and the vapour ignites as it issues from several small openings.

561. *Volatile Oils and Water.—Experiment.*—Drop some oil of cumin upon water; the oil floats on the surface without mixing with the water, for most of the volatile oils are *lighter* than water; but there are some, such as oil of cinnamon, oil of cloves, and oil of bitter almonds, which are heavier than water, and sink in it.

If the mixture is briskly shaken, the water becomes turbid, because the oil is thus divided into small, invisible globules, which are kept suspended in the water. The water may be again clarified by filtration, but it retains the smell and taste of the oil, since a small quantity of it remains dissolved. Many such solutions are kept in the apothecaries' shops, under the name of *medicated* or *distilled waters*. It is well to keep them protected from the light, and in full vessels,—both light and air having a decomposing action on the volatile oils. They are commonly prepared by distilling with water the vegetable substance containing the oil, as thereby a more intimate combination of the water with the oil is effected than by merely shaking it up.

562. *Volatile Oils and Alcohol.—Experiment.*—Add a drop of oil of cumin to one ounce of strong alcohol; it dissolves readily and entirely. All the volatile oils are soluble in alcohol, most of them even in alcohol of eighty per cent.; but the non-oxygenated oils, such as oil of turpentine, oil of lemons, &c., only in absolute alcohol. If an ounce of water, in which half an ounce of sugar has previously been dissolved, is added to the solution, we obtain cumin-cordial. In this manner, by the aid of various aromatic oils, the innumerable *cordials* or liquers occurring in commerce are now generally prepared (preparation of cordials in the cold way). They were formerly manufactured from aromatic seeds, flowers, herbs, &c., by pouring brandy over them, the brandy being afterwards distilled or drawn off, whereby a spirituous solution of the volatile oils was likewise obtained.

Experiment.—If some drops of oil of bergamot, orange-flower, lavender, or rosemary are dissolved in half an ounce of strong alcohol, we obtain a spirit of a very pleasant odour. In a similar way the innumerable kinds of perfumed waters are prepared, at the head of which stands the well-known *eau de Cologne.* The fumigating spirit also, which, instead of the fumigating powder, is often sprinkled on a warm stove, has a similar composition. Camphorated spirit, much used as an external remedy, is likewise a solution of camphor in alcohol.

563. The volatile oils are not only dissolved by alcohol, but also by *ether* and concentrated *acetic acid.* A solution of oil of cloves, cinnamon, bergamot, and thyme, in acetic acid, is used as *aromatic vinegar*, on account of its refreshing odour.

The volatile oils may also be mixed with *fat oils*, and with some kinds of tallow and lard; hence by means of them an agreeable odour may be imparted to the latter, as, for instance, in hair oils, pomatum, &c., or grease-spots be dissolved and removed by them from various articles. Volatile oils mixed with alcohol yield, when shaken up with olive oil, a turbid, milky liquid, because the alcohol does not dissolve the olive oil; this behaviour may be taken advantage of for testing the purity of mercantile oils.

564. *Experiment.*—Rub a piece of sugar for some time on the rind of a fresh lemon; the hard sugar tears the cells in which the oil of lemons is enclosed, and the oil is attracted into the pores of the sugar. This, when reduced to powder, is called *oleo-saccharum*. Such mixtures are commonly prepared in pharmacy by triturating together powdered sugar and volatile oils.

565. *Experiment.*—If you add some drops of oil of turpentine to *iodine*, a brisk emission of sparks ensues, since a part of the hydrogen is expelled and replaced by the iodine. The same phenomenon is occasioned by all non-oxidised oils, but not by those oxidised; therefore iodine may serve as a test, although not a very delicate one, for ascertaining whether oils of the latter class have been adulterated with oil of turpentine.

566. *Conversion of the Volatile Oils into Resins.—Experiment.*—Let some oil of turpentine remain exposed to the air for some weeks, in a cup covered with paper, and afterwards put the cup in a warm place to evaporate the oil; it will not entirely volatilise, but will leave at first a viscous, and afterwards a vitreous residue. This residue is resin. *All volatile oils are converted into resin, because they gradually absorb oxygen from the air;* which, as in the case of the transformation of alcohol into vinegar, first combines with a portion of the hydrogen of the oil, forming water, and then unites with the oil itself. Alcohol, on exposure to the air, is converted by the removal of hydrogen into aldehyde, then by the reception of oxygen into acetic acid; the volatile oils are, in a similar manner, first converted by the air into *turpentine* (mixtures of volatile oils and resin), and then into *resins*. Oil of turpentine consists of $C_{10}\ H_{16}$; resin, of $C_{10}\ H_{15}\ O$; consequently the former has only to give up one atom of hydrogen, and receive one atom of oxygen, to be converted into resin. This explains very simply why the volatile oils become gradually viscous and scentless on being kept, and more rapidly in large and only partially filled bottles than in small ones, and why the drops running down on the outside of the bottles dry up first into a sticky, and then into a resinous mass. Old oil of turpentine is, for this reason, not suitable for removing grease-spots; it dissolves, indeed, the fat or resin dried into the material, but leaves behind new spots of resin in their place.

The volatile oils are very rapidly changed by nitric acid into non-volatile resinous substances. There are sometimes simultaneously formed, in this case, peculiar *organic acids* ; for example, terebinthic acid from oil of turpentine, camphoric acid from camphor, &c. Many such acids are also spontaneously generated together with resin, by long standing in the air ; for instance, cinnamic acid in the oil of cinnamon ; or are found already formed in the volatile oils ; as, for instance, caryophyllic acid in oil of cloves, &c.

567. Metallic arsenic has no smell ; neither has arsenious acid (arsenic combined with oxygen). We perceive the striking odour like that of garlic only at the very moment when the arsenic is combining with the oxygen. The same thing seems to happen with regard to the odour of volatile oils, so that we may assume that the odour is emitted *because* the oils are combining with the oxygen of the air, and *while* they are combining. Fresh oils, and those distilled with exclusion of air, and old resinified oils, either do not smell at all, or emit quite an unusual odour.

XI. RESINS AND GUM-RESINS (RESINÆ ET GUMMI-RESINÆ).

568. *Turpentine and Balsams.*—Whoever has been in a forest of fir or pine trees must certainly have noticed the yellow, transparent juice, having the consistency of honey, which exudes from these trees, and he may perhaps have observed also that it sticks to the fingers, and cannot be washed off again by mere water. This juice is *turpentine.* It is procured in large quantities by incisions made in the trees. That obtained from the European fir-trees is turbid, and has a thick consistency ; it is called *common turpentine ;* but *Venice turpentine* is the more transparent and more fluid sort, which is procured from larch-trees. A yet finer quality, yielded by the American silver-fir, is called *Canada balsam.*

The term *balsam* is applied also to several other resinous vegetable juices, which exude from some tropical trees, or are boiled out from them. The best known are the yellowish *balsam of copaiba,* an important medicine, the blackish-brown *balsam of Peru,* and the brownish-grey *balsam of storax* (liquid storax), the last two of which are generally used for fumigrating, on account of their agreeable odour, which resembles that of vanilla.

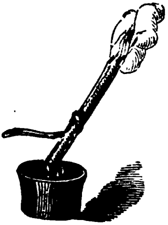
All these turpentines and balsams are to be regarded as solutions of resin in volatile oils, into which two constituents they are separated when distilled with water. (§ 551.) The same thing happens when they are allowed to stand for some time in an open vessel in a warm place, except that in this case the oil volatilises, and diffuses itself in the air.

569. *Preparation of the Resins.*—*Experiment.*—Spread a little turpentine upon a board, and put the board for some time near a heated stove; the oil of turpentine evaporates, but the *resin* remains behind as an amorphous brittle mass. In some countries, incisions are made through the bark of fir-trees, and the turpentine which exudes is allowed to evaporate on the trees themselves, and after it has been purified, by melting and straining through a colander, from the woody particles adhering to it, it is brought into market under the name of *rosin*, *white pitch*, or *Burgundy pitch*. Large quantities of such resin are now exported from the forests of America (American rosin). Two different operations are going on during the evaporation of the turpentine; a part of the volatile oil existing in it evaporates, and occasions the peculiar smell of the pine forests, but another part attracts oxygen from the air, and is converted into resin. (§ 556.)

Resinous juices, which harden in the air, forming solid resins, exude, either spontaneously or through incisions made for the purpose, not only from our fir-trees, but also from many other trees and shrubs, particularly those of hot climates. Almost all the resins occurring in commerce are procured in this manner.

Experiment.—Resin is deposited most abundantly in those parts of the trees where the branches join the trunk; wood impregnated with such resin is called resinous wood. If a piece of resinous wood is lighted at the upper end, and held by a wire in an oblique position over a basin of water, one portion of the resin burns up with a sooty flame, while another part is melted by the heat, and runs down into the vessel beneath. *Resin is not soluble in water;* hence it hardens in the latter without mixing with it. In this manner—*by*

Fig. 210.



roasting—resins may be prepared from many plants; but the colour of the resins thus prepared is usually dark, because some of the resin has become burnt, and is thereby richer in carbon, according to the general law, that hydrogen is always burnt before carbon.

Experiment.—Pour strong alcohol upon some resinous wood, and let it remain for a day in a wm place; the resin is dissolved, and the woody fibre remains behind. The solution is poured into eight times its quantity of water, which is thereby rendered milky, because the resin is precipitated, but in such a state of fine division that it floats about in the water in the form of small globules. If this milky fluid is heated to the boiling point, the resinous particles soften and unite with each other in small lumps, which may be taken out and pressed together in larger masses. This is a third method of extracting resin from vegetable substances.

DIFFERENT SORTS OF RESIN.

570. The following are the most important resins:

Pine-resin is the resin of our pine-trees.

Galipot is a very clear yellowish-white kind of pine-resin, imported from France.

Copal is of a yellowish-white or brown colour, and very hard; it comes to us covered with sand and earth, from which it is freed by washing it with lye and by scraping. The copal of the West Indies and Africa has a smooth surface, but that of the East Indies is wrinkled and uneven. It is insoluble in common alcohol, but it partly dissolves in absolute alcohol, and dissolves entirely in ether; the East India copal dissolves the most readily.

Dammara resin (Kauri or *Cowdee)* is colourless or yellowish, tolerably hard; comes from the East Indies.

Mastic is yellowish, transparent, comes in rounded tears, and exudes from a species of Pistacia, a tree growing principally in Greece.

Sandarach, much resembling mastic, but yet more brittle, is the product of an evergreen tree which grows in Africa.

Lac exudes from several species of Ficus growing in the East Indies, through punctures made by a small insect called the Coccus lacca.

a.) *Stick-lac* is the name given to the juice dried upon the twigs.

b.) *Seed-lac,* when it is broken off from the twigs.

c.) *Shell-lac,* when it is melted and strained through a cloth to remove impurities. The liquefied resin is commonly made to drop upon large leaves, and cooled; it thus spreads out into thin plates. The finest shell-lac has an orange colour, that of inferior quality a dark-brown colour. It is very hard and tenacious, and for this reason is generally used in the manufacture of sealing-wax.

Benzoin flows from incisions made in a tree of the East Indies. The resin exuding during the first three years forms milk-white grains, but that formed afterwards is yellow or brown. Both sorts are kneaded together; hence the amygdaline appearance of the common benzoin. Its agreeable odour, somewhat like that of vanilla, has rendered it a popular ingredient in fumigating pastilles, and also in cosmetic lotions for beautifying the skin. One sixth of it consists of benzoic acid.

Dragon's-blood is a brownish-red coloured resin; it is the produce of several palm-trees growing in the East Indies.

Guaiacum, a brownish-green resin, and also an olive-coloured variety of the same, are obtained by roasting guaiacum-wood, and are considerably used in medicine.

Resin of jalap is extracted by alcohol from jalap-roots.

Many other resins are used in pharmacy, for instance, anime, tacamahac, elemi, &c.

571. *Bitumen.*—Two other resins, amber and asphaltum, which are obtained from the earth or from the sea, remain to be mentioned.

Amber probably proceeds from the forests of a primeval age, which have been submerged by floods of water. The resins form an exception to the general rule,—they do not putrefy nor decay, like other organic bodies. Amber-resin might accordingly remain for centuries unchanged in the earth, or in the sea, while the trees from which it exuded were changed into mould and earth, or, chemically speaking, became decomposed into carbonic acid, water, &c. Amber is found most frequently in the Baltic and on its coasts, and in many brown-coal mines. Its hardness and tenacity are well known, since it is formed into various articles which are usually manufactured from glass or horn. It differs from other resins, as it yields on fusion *succinic acid*, and undergoes a change, in consequence of which it then becomes soluble in alcohol and oils, which scarcely attack it in its unmelted state. By longer fusion it becomes black, and is then called *amber-colophony;* it yields, at the same time, a very disagreeably smelling empyreumatic oil, oil of amber, which is sometimes used in medicine.

Asphaltum, or *pitch of Judæa*, is likewise a mineral resin, which is found in many of the seas of Asia, particularly in the Dead Sea. It has a black colour, and great similarity to the black resin which is obtained by the evaporation of coal tar (*factitious asphaltum*). Asphaltum is found in other places, and has a soft consistency, and resembles turpentine (*Barbadoes tar*); this kind has in later times been mixed with sand and lime for making artificial pavements and tiles. It is very probable that these two resins, as also petroleum, are derived from layers of pit-coal which have been heated in the interior of the earth by volcanic fires.

572. Similar resinous substances, of a black colour and disagreeable odour, are also artificially formed whenever animal and vegetable substances are heated with an insufficient supply of air, especially during dry distillation of the same. When in a fluid form, they are called *tar;* in a solid form, *black pitch.*

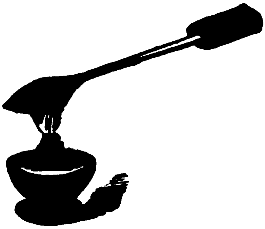
PROPERTIES OF RESIN.

573. It was stated, when speaking of amber, that resins are substances which *do not undergo decay*—indeed, they have the power to protect from decomposition other bodies which very readily pass into decay or putrefaction: for instance, flesh. On this account they were formerly used for embalming dead bodies, which are now found, after the lapse of centuries, dried to mummies, in the pyramids of Egypt.

574. *Resin and Water.*—The resins as a general rule are *insoluble* in water, and therefore tasteless; but some of them in very small quantities may be dissolved, and these usually have a bitter taste. But many of the resins which occur in commerce contain some water in a state of minute division, and are thereby rendered dull and opaque; common pine-resin and boiled turpentine furnish examples of this.

Colophony or Rosin.—Experiment.—Heat a piece of the

Fig. 211.



solid turpentine (§ 551), or else some pine-resin, in a spoon, till all the water is evaporated; the *anhydrous resin* will now appear perfectly transparent. In this state it is called *colophony*, or *rosin*, being *white* when it is moderately heated, but *brown* when the heat is so strong as to convert a part of the resin into *black pitch*. Colophony is so brittle that it may easily be reduced to a powder. When the bow of a violin is rubbed with it, the rosin powder formed remains adherent to the hairs, and these then again adhere better to the strings of the violin. A similar effect is produced on the cords which sustain the weights in clocks when they are rubbed with rosin to prevent their slipping. The resins, accordingly, exert an effect contrary to that of oil; by resin, a rough, uneven surface is produced; by oil, a smooth, slippery surface.

575. *Action of Heat on Resins.*—The experiment first performed reveals at the same time another property of resin; namely, its easy *fusibility*. Most of the resins require, in order to become fluid, a heat which is somewhat higher than that of boiling water. If melted rosin is poured upon a board, it spreads, and forms after hardening a solid, brilliant coating on the wood. The resins are hereby well adapted for protecting wood or metal from the penetration of air or water. For this reason, iron rails and iron ornaments are covered with a coating of pitch, to prevent them from being so quickly oxidised by the oxygen of the air; for the same reason, also, wine-casks and beer-barrels are smeared with pitch, that no air may penetrate into the casks, and that no beer may penetrate into the staves. The wood-work of ships, the hatches, &c., are covered with tar, to keep out the sea-water and rain; and finally, also, the solid and tenacious resin, shell-lac, is employed in the form of sealing-wax, as a protection against curiosity.

Sealing-wax.—Experiment.—Melt together in a small ladle one-fourth of an ounce of pale shell-lac, one drachm of turpentine, one drachm of cinnabar, and three-fourths of a drachm of prepared chalk; scrape out the mass while yet soft, and roll it out into sticks by the hands, moistened with water. The turpentine renders the sealing-wax more inflammable, and the cinnabar imparts to it the favourite red colour. Various other colours are given to it by chrome-yellow, ultramarine, Brunswick-green, lamp-black, bronze-powder, &c.

576. *Rosin-gas.—Experiment.*—When rosin is heated above its melting point, it *kindles* and *burns* with a luminous and sooty flame, leaving behind some charcoal. Therefore powdered rosin, when blown into the flame of a lamp, burns vividly. In many places *illuminating gas* is prepared from it, by letting it drop in a melted state upon coke, which is heated to redness in an iron cylinder (*rosin-gas*).

Burnt Pitch.—If the rosin, after it has burnt for some time, is extinguished by putting a board over it, we shall have as a residuum a black, burnt resin, *ship-pitch*, and *cobbler's wax*, possessing great tenacity.

Lamp-black.—Experiment.—If you hold a cone made of blotting-paper over burning pine-wood, it will soon become lined with soot. The well-known *lamp-black* is prepared on a large scale by a similar method. Resinous wood, or the resin itself, is burnt with an insufficient supply of air in a stove furnished with long flues, or with a chamber in which the smoke deposits its carbon on its passage through.

Experiment.—If some amber is scattered on glowing charcoal, a vapour having a pleasant balsamic odour is emitted from it as it smoulders away. Amber, frankincense, benzoin, and mastic are on this account frequently used for fumigating purposes.

577. *Electrophorus.—Experiment.*—Rub a stick of sealing-wax for some minutes upon a piece of cloth, and then approach it to some small shreds of blotting-paper; they will fly up to the sealing-wax, and remain adhering to it for some time. This attraction is effected by electricity (*resinous* or negative electricity), which is generated in the resins by friction. If you pour a mixture of shell-lac and rosin into a tin plate in order to obtain a larger surface, you will be enabled to extract the electricity from it in the form of sparks, and to collect it; this is called an *electrophorus* (bearer of electricity). This mysterious power has received the name of *electricity* from ἤλεκτρον, the Greek word for amber, in which the electrical phenomena were first observed.

578. *Resin and Alcohol.*—*Experiment.*—Wrap half an ounce of sandarach in paper, and break it with a hammer into smaller pieces; then mix it with a drachm of sand, which has been previously freed from its finer particles by elutriation, and afterwards thoroughly dried, and pour the mixture into a glass vessel, with two ounces of strong alcohol. Tie a piece of bladder over the vessel, and let it remain for several days in a warm place, frequently stirring it round. The clear solution of resin thus obtained is called *lac-varnish*, because, when smeared over metal, wood, or paper, it leaves behind, after the alcohol has evaporated, a varnished, shining coat. If alcohol is poured upon the sandarach, unmixed with sand, the resinous powder will cake together on the bottom of the vessel; forming a tenacious mass of resin, which dissolves much more slowly. To *lacquer* or *varnish*, then, is to coat the surface of anything with resin. By this coat of varnish, articles not only acquire a beautiful brilliancy, but are rendered at the same time impervious to air and water. When paper articles, as drawings, maps, &c., are to receive a coat of varnish, size or a solution of gum must previously be spread over them several times, as the solution of resin would otherwise penetrate into the fibres of the paper, and render it grey and transparent. This imbibition is usually prevented in wooden articles by smearing them with linseed oil before putting on the varnish. When the varnish is applied on places that are wet, white opaque spots are formed, because the resin is separated by the water as a dull white powder.

Experiment.—Dissolve half an ounce of shell-lac in strong alcohol; a turbid liquid is obtained, as the shell-lac contains, besides the resin, small quantities of wax and mucilaginous substances, which float about undissolved in the solution of resin. This solution is also employed as a lac-varnish, but much more frequently as the so-called *French polish* of the cabinet-makers; that is, as a solution of resin, which they rub continuously upon the wood with a ball of linen, until the alcohol has evaporated. By this means a still smoother and finer polish is obtained than by merely applying the resinous solution with a brush, the marks of which frequently remain visible. The finer articles of furniture are usually French polished, the more common ones varnished.

579. *Resins and Oils.*—*Experiment.*—Mix half an ounce of dammara resin with some sand, and pour over the mixture

two ounces of oil of turpentine; after a few days you will obtain an almost complete solution, *as the volàtile oils are likewise able to dissolve resins.* These solutions are also frequently employed as lac-varnishes; they dry, indeed, more slowly, but form a more tenacious coating, which is less liable to crack. The paler and finer varieties of varnish are principally prepared from amber, copal, dammara, shell-lac, sandarach, and mastic; the inferior and darker kinds, from amber-colophony, common colophony, turpentine, asphaltum, &c. A yellow colour is sometimes given to the pale varnishes by the addition of dragon's-blood, or gamboge.

The resins are likewise soluble in *fat oils.* Many of the ointments and plasters of the apothecaries, consist of mixtures of fats and resins, and it is the latter which communicate to the former the property of adhering to the skin. Turpentine is usually employed for this purpose.

580. *Resin Soap.—Experiment.*—Boil in a jug a quarter of an ounce of rosin, with one ounce of strong solution of potassa or soda, and then gradually add more of the latter by spoonfuls, until a sample of the mixture dissolves in hot water, forming a clear liquid. The mass hardens, on cooling, into a solid *soap* (a compound of the resinous acid and potassa, or soda). The resins, as we see, comport themselves towards strong bases like the fatty acids, and hence have an extensive application in the manufacture of soap, being mixed with the fats in different proportions in the manufacture of the cheaper kinds of soap.

Experiment.—Mix a solution of rosin soap with a solution of alum; an insoluble combination of *resinous acid and alumina* is formed. Rosin soap is employed for the sizing of paper; it is first introduced into the vat containing the pulpy mass of which the paper is to be made, and then the solution of alum is added. There is thus formed round each fibre of the paper a thin layer of insoluble alumina soap (resinous acid and alumina), which prevents the spreading of the ink. According to the old method, the sheets of paper were passed through a solution of size, whereby only a thin layer of size was formed on the surface of the paper. This kind of paper allows the ink to spread, when the coat of size has been scraped off by erasure; but this may be prevented by rubbing some resin—sandarach is the best—upon the spots erased.

Resins combine with bases, and their solutions redden litmus-paper. Accordingly, they may be regarded as *acids*.

581. *Composition of the Resins.*—By alternate treatment of the resins with cold or hot, weak or strong alcohol, or with ether, various kinds of resin may be extracted from most of them, which have been designated by the terms alpha (α), beta (β), or gamma (γ) resins. The natural resins are accordingly to be regarded as mixtures of several simple resins.

Only the three elements—carbon, hydrogen, and oxygen (C, H, O), occur in the resins. That they contain somewhat more oxygen, and less hydrogen, than the volatile oils, has already been stated (§ 566); but, nevertheless, they belong to the *bodies rich in hydrogen*, since they burn with a strong flame.

GUM-RESINS.

582. If you divide the stem of a poppy, lettuce, or celandine, a white or yellow juice exudes, which dries up in the air or by the heat of the sun, forming a yellow or brown amorphous mass. This milky juice consists of a solution of gum, intimately mixed with minute drops of resin; thus it forms a natural emulsion. This kind of dried, half-resinous, half-gummy vegetable juice is called, from these two proximate constituents, *gum-resin*. Many plants of hot climates are especially rich in such resins, and from them are principally obtained the gum-resins occurring in commerce, which have various applications, particularly in pharmacy. Among the most important are,—

Ammoniac (gum ammoniac), the inspissated milky juice of an African umbelliferous plant; it has a yellowish or brown colour, and a strong, peculiar smell and taste.

Asafœtida, the juice of a Persian umbelliferous plant, having a very unpleasant smell, like that of garlic; it has a milk-white appearance when freshly broken, but quickly changes in the air and light into a pink colour.

Aloes, which has a brown or black colour, and is exceedingly bitter; it is the dried juice of the aloe-plant, which grows in great abundance on the Cape of Good Hope and the adjacent islands.

Euphorbium, which comes in brownish-yellow tears from the African plant Euphorbia Canariensis, and contains a very acrid substance, in consequence of which it vesicates the skin, and, when snuffed, excites inflammation of the nostrils and the most violent sneezing.

Galbanum, a yellowish or brownish substance, having a strong and peculiar odour; it is obtained from an evergreen plant of Persia.

Gamboge, which occurs in orange-coloured masses or sticks; it is obtained from the leaves of an East Indian plant, and is principally used as a yellow water-colour in painting.

Myrrh; the better sorts occur in pale brownish-yellow fragments, the inferior sorts in dark brownish-red pieces; it has a bitter taste and a balsamic odour, and exudes from incisions made in a tree growing in Arabia.

Frankincense (olibanum), which comes in yellowish-white, brittle, roundish fragments; the juice, inspissated in the air, is obtained from a tree in Persia. It yields an agreeable odour upon glowing coals, and hence is much used for fumigating purposes.

Opium, a milky juice, which exudes from incisions made in the heads of unripe poppies, and is dried by exposure to the air; it occurs in large lumps of a dark-brown colour, having a bitter taste and an offensive narcotic odour. The soporific effects of it are well known.

Lactucarium, of a brown colour, and having somewhat the odour of opium; it is the inspissated juice of several kinds of lettuce.

Opoponax, Sagapenum, Scammony, and many others.

PROPERTIES OF THE GUM-RESINS.

583. *Experiment.*—Triturate some one of the gum-resins with *water;* the gum is hereby dissolved, and a turbid, milky liquid (emulsion) is obtained. If this is boiled for some time, the softened particles of resin cake together, and separate as lumps; the liquid, having become clear, contains now only the gum in solution.

Experiment.—If strong *alcohol* is poured over the gum-resins, and they are digested together for some time, the resin only is dissolved, while the gum remains undissolved. The well-known tincture of myrrh is a solution in alcohol of the resinous part contained in the myrrh. Most of the gum-resins contain, besides resin and gum, a small quantity also of volatile oils, to which they owe their peculiar *odour.*

CAOUTCHOUC (GUM ELASTIC).

584. There exudes from several large South American trees, when incisions are made in them through the outer and inner bark, a milky juice, which dries in the air into a white elastic mass, quite insoluble in water and alcohol. It is gum elastic, or caoutchouc. The drying proceeds more rapidly when the milky juice is spread upon moulds of clay or loam, and then suspended over a fire. If, after the gum is dry, the clay or loam is removed by washing, hollow articles of caoutchouc are obtained, but which have a grey or black appearance on account of the soot mixed with them.

Experiment.—Caoutchouc at the ordinary temperature is hard and stiff, but it becomes soft when it is put into hot water or in a warm oven. Cut from one of these caoutchouc bottles, softened by heat, a square piece, apply it evenly round the ends of two glass tubes, and then clip off with a pair of scissors the ends of the strip in the direction marked out in the annexed figure: the fresh surfaces of the caoutchouc adhere firmly to each other (but still more closely when they are pressed together with the nail, yet without touching the freshly cut surfaces), and thus is formed a tube, which, firmly tied at both ends, connects the two glass tubes air-tight to each other. In this manner, the glass tubes occurring in chemical apparatus are made pliant and flexible, and the risk of breaking them is thereby diminished.

Fig. 212.

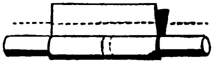


Fig. 213.

Experiment.—Pour some ~~[illegible]~~ Benzoline upon a few pieces of caoutchouc; the caoutchouc will swell up in it, and may then be triturated into a uniform mass. When melted with shell-lac, the mass affords a very permanent cement for wood, stone, and iron (marine glue).

Experiment.—If ether, oil of turpentine, or oil of coal-tar is poured upon caoutchouc, a complete solution is obtained. Solutions of this kind are now frequently employed for rendering fabrics waterproof (*Mackintosh*). When strongly heated with linseed-oil, caoutchouc forms a homogeneous, tenacious, black mass, which is very well adapted for smearing shoe-leather.

Experiment.—When caoutchouc is held in a burning candle, it takes fire and burns with a vivid, sooty flame, like petroleum or oil of turpentine, and melts into a black, glutinous residue. This melted caoutchouc is very serviceable for preventing the sticking of glass stoppers in bottles, in which lye, &c., is kept; the stoppers, when coated with it, remain lubricous for a long time.

Caoutchouc acquires an extremely high degree of elasticity by intimately mixing it with sulphur, or sulphuret of arsenic (*vulcanized Indian rubber*).

Caoutchouc is one of the few solid bodies which contain *no oxygen;* it consists only of carbon and hydrogen, so that it may be regarded, as it were, as condensed petroleum, or as condensed illuminating-gas.

Gutta Percha.—Under this name, within a short time, a substance resembling caoutchouc has occurred in commerce, which is procured from the milky juice of several East Indian trees; it has the advantage over caoutchouc, that it becomes quite soft and plastic by moderate heating, but hard again on cooling, and has found already various applications in the arts.

RETROSPECT OF THE FATS, VOLATILE OILS, AND RESINS.

1. The fats, volatile oils, and resins are among the very generally diffused substances of the vegetable kingdom; most of them comport themselves like indifferent bodies, many like feeble acids.

2. As occurring in nature, they are mixtures of several similar substances, which are,—

a.) The fats; mixtures of solid fats (stearine, margarine) and of fluid fats (oleine, glycerine).

b.) The volatile oils; mixtures of solid stearoptene and fluid oleoptene.

c.) The resins; mixtures of several different kinds of resin (alpha, beta, gamma resins, &c.).

3. As respects their elementary constitution, they consist only of the three elementary substances, carbon, oxygen, and hydrogen; but they are always *poor in oxygen and rich in hydrogen.* (Some volatile oils contain no oxygen.)

4. On account of the excess of hydrogen,—

a.) They burn, when ignited, with a brisk flame, and yield, on decomposition by a red heat, much combustible gas.

b.) Most of them are so light that they float upon water.

c.) They dissolve only in liquids which are likewise rich in hydrogen and poor in oxygen; for instance, in alcohol and ether, but not in water.

5. They are either liquid, or are easily rendered so, even when gently heated.

6. The *fats* of animals have exactly the same constitution as the vegetable fats.

7. By the addition of oxygen many kinds of fat become solid and hard (varnish oils), others, on the contrary, become rancid without hardening (unctuous oils).

8. The fats are resolved, by strong inorganic bases, into peculiar acids insoluble in water (fatty acids), and into an organic base (oxide of glyceryle). The separated fatty acids hereby combine chemically with the inorganic bases, forming *soaps.* The alkalies form, with the fatty acids, soaps which are soluble in water; the oxides of the earths and metals, on the contrary, form soaps which are insoluble in water.

9. The *volatile oils,* by the addition of oxygen, pass into resins; often, also, at the same time, into acids.

10. The *resins* evince no great affinity for oxygen; at least they do not alter, however long they may be exposed to the air.

11. Many of the resins combine with the alkalies, forming soaps soluble in water; with the earths and metallic oxides, forming soaps insoluble in water (resinous soaps).

12. *Balsams* are mixtures of resins with volatile oils; *gum-resins* are mixtures of resins with gum.

XII. EXTRACTIVE MATTER.

585. *Extracts.*—The vegetable substances hitherto considered are, if we except the volatile oils and some resins, mostly without taste and without any striking medicinal effect; most of them occur very generally diffused in the vegetable kingdom, and are found in almost all vegetables. But we observe in many plants a peculiar taste, and when swallowed a peculiar effect upon our bodies; consequently, there must be other special substances present, from which the taste and effect proceed. Wormwood and rhubarb have a bitter taste, pepper and

henbane a pungent and sharp taste, the roots of couch-grass and of liquorice a sweet taste. When introduced into the stomach, wormwood is stomachic, rhubarb purgative, pepper stimulating, henbane narcotic, &c. These and similar observations must, even at an early period, have excited the attention of man, and led him to extract the sapid and medicinal principles from the plants, and to use them in medicine. This extraction was effected in a simple manner—from the juicy parts of the plants by expression; from the drier parts, by treating them with cold water (maceration), or with hot water (infusion), or by boiling them with water (decoction). As the vegetable juices or extracts would soon become sour or mouldy, the water is evaporated away; by this means a pulpy or pasty mass, or, on more complete desiccation, a solid amorphous mass, is obtained, which is called an *extract* (watery extracts), and may be kept for years unchanged and undecomposed. Sometimes, instead of water, alcohol or ether is used as a solvent (alcoholic and ethereal extracts). Many of these extracts are always kept by the apothecaries as medicines, and half an ounce of them frequently contains as much active matter as one pound, or even several pounds, of the vegetable substance from which they were prepared.

It has already been stated that most of the vegetable juices contain sometimes larger, sometimes smaller, quantities of starch (sediment), mucus, gum, sugar, tannin, chlorophyll, vegetable albumen, salts, acids, &c.; hence, as none of these substances volatilise on evaporation, they must also be present in the watery extracts. It is likewise clear, that in the spirituous and ethereal extracts all those substances which can be dissolved from the vegetable matters acted upon by either alcohol or ether must be present—for example, resins, fats, &c. *The extracts may, accordingly, be regarded as mixtures of various kinds of vegetable matter*, as mixtures of known with unknown vegetable matter, of that having taste with that having no taste, of the active with the inert, of the colourless with the coloured, &c.

586. *Extractive Matter.*—On closer examination of the vegetable juices or extracts, it has been found that after the known substances, such as starch, sugar, albumen, &c., have been removed from them, a brown or black uncrystallisable, soluble mass remains behind, which generally possesses in a

greater degree the taste and the medicinal effect of the plant from which it has been extracted. This mass is called *extractive matter*, and is distinguished according to its properties:—*bitter* (in wormwood, buckbean, aloes, colocynth, &c.), *aromatic bitter* (in the root of the sweet-flag, in hops, &c.), *acrid* (in senega-root, soapwort, &c.), *sweet* (in liquorice-root, root of couch-grass, &c.), *narcotic* (in hemlock, henbane, &c.). The name was obviously a very convenient one, since it applied to all the innumerable vegetable substances not thoroughly examined, which possessed a dark colour and did not crystallise, however different might be their chemical constitution. How great this difference may be we infer from this, that most vegetable substances, for instance, sugar and gum, when they are boiled for a long time, or merely exposed to the air, are converted into brown, uncrystallisable compounds.

587. The reason why all extracts have a brown or a black colour is to be sought for in this ready changeableness of vegetable matter.

Experiment.—Pour upon some ounces of sliced liquorice-root six times the quantity of boiling water, and, after it has stood for some days, express the liquid; when this has been filtered through blotting-paper, it is clear, transparent, and of a sherry-wine colour. Upon evaporation, we obtain from it a black extract, the well-known Spanish liquorice, which, when redissolved in water, no longer yields a yellowish, but a dark-brown liquid. Not only the colour, but the taste also, has perceptibly changed. Both changes clearly show, that during the evaporation a chemical decomposition of the dissolved matter has taken place. It is very similar to that which happens during the putrefaction or slow oxidation of wood; namely, oxygen is absorbed from the air, and some hydrogen and carbon are hereby oxidised into water and carbonic acid, whereby substances similar to humus, richer in carbon, and consequently darker-coloured, are formed. These are in part dissolved in the water, and cause the dark colour of the liquid; but they are in part no longer soluble, and therefore separate from the solution as a dark-coloured sediment. This sediment has been designated by the likewise very indefinite term, *oxidised extractive matter*. From this it results as a general rule in the preparation of extracts, that the evaporation of the vegetable juices should be conducted, if possible, with exclusion of air, and at a gentle heat; it is best done over the water-bath.

588. *Crystallisable Extractive Matter.*—In modern times, several of these peculiar substances have been obtained in a crystalline form, consequently as definite and independent compounds. Many of these behave very much like the inorganic bases (potassa, soda, ammonia, &c.); that is, they are able to neutralise acids and to form salts with them: *these are the organic bases.* (§ 596.) Others, on the contrary, possess neither basic nor acid properties,—they are *indifferent*, and may be called *crystallisable extractive substances*, at least until their chemical behaviour shall have been more accurately ascertained by further investigations. As yet, too little is known about them to enable us to express any decided opinion concerning them. The number of plants now known exceeds a hundred thousand, and it is not improbable that peculiar extractive matters are to be found in most of them; consequently they present a fine field for new discoveries. After what has been said, we may include under the term *extractive matter* all sorts of chemical substances of indifferent crystallisable, and of indifferent brown, uncrystallisable matter, to which in most cases we ascribe the peculiar taste and the peculiar medicinal effects of plants. Most of them are characterised by a bitter taste, and hence are frequently called *bitter substances.* Some of them, namely, those which are insoluble in water, do not evince the taste peculiar to them until they are dissolved in some other liquid, for instance, in alcohol or ether.

589. The *best known of these peculiar substances* will now be briefly referred to. Their names (as also the names of colouring matters and of the organic bases) are usually formed from the Latin names of the plants, with the addition of the affix *in* or *ine.*

Absinthine, from wormwood, very bitter; a colourless crystalline mass.

Amygdaline, from the bitter almonds, slightly bitter, crystallises in lustrous silky scales; it has the very remarkable property of being converted into a volatile oil containing prussic acid (oil of bitter almonds) when it is mixed with dissolved vegetable albumen.

Centaurine, from the Chironia centaurium, bitter; as yet only known as an extract.

Cetrarine, from Iceland moss, bitter; a white powder.

Columbine, from columbo-root, very bitter, crystallises in white prisms.

Gentianine, from gentian-root, very bitter, crystallises in yellow needles.

Imperatorine, from masterwort, very acrid and burning; in white crystals.

Lupuline, from hops, an agreeable bitter; a white or yellowish powder.

Meconine, from opium (poppy-juice), acrid to the taste; in white crystals.

Picrotoxine, from the seeds of the Cocculus Indicus, very bitter, narcotic, and poisonous; in white needles.

Quassine, from the wood of the quassia, very bitter; in white crystals.

Santonine, from worm-seed, bitter, in white crystals.

Scillitine, from squill, nauseously bitter; a white amorphous mass.

Senegine, from senega-root, acrid and pungent; a white powder.

Glycyrrhizine, from liquorice-root, very sweet; a pale-brown amorphous mass.

Populine, from the leaves and bark of the poplar, sweet; crystallisable in white needles.

Asparagine, from asparagus, having an insipid taste; in white crystals.

Smilacine, from the root of the sarsaparilla, tasteless; in white crystals.

By far the greater proportion of these substances consist of the three elements, *carbon*, *hydrogen*, and *oxygen;* some few only contain also a little nitrogen.

XIII. COLOURING MATTER, OR DYES.

590. When the peculiar substances which have been treated of in the previous section, under the name of extractive matters, are themselves coloured, or become so by the action of other substances, they are called *colouring matter*, or *dyes.* Most of

those colours whose inimitable splendour and variety we admire in the flowers of plants, are so exceedingly evanescent, that they fade or disappear on withering or drying, and very rapidly, especially when they are exposed at the same time to the sunshine. The same happens when we attempt to extract or separate the colouring matter by expression, or in some other way. A few plants only contain, sometimes in the roots or the wood, sometimes in the leaves or fruit, colouring juices of such permanency that they are more difficultly and slowly decomposed by the light; these may be extracted, and then employed for colouring other substances. These colours, however, are turned white by chlorine or sulphurous acid (bleached). Their extraction may be effected in most cases by water, sometimes also by alcohol or other liquids. As some extractive substances in the former section have been obtained in a crystalline form, so also crystallised colouring substances have been separated from coloured extractive matter; but other colouring principles, on the contrary, are only known in the form of extracts. The names which have been given to these colouring substances likewise terminate in *ine*, and are included in parentheses in the following list of the most important vegetable colouring matters.

591. *Red and Violet Colouring Substances.*

a.) *Madder* is the ground root of the Rubia tinctorum. The fresh root looks yellow, but when exposed to the air it becomes red, owing to the absorption of oxygen, and yields a superior permanent or fast red colour in dyeing, for instance, the brilliant Turkey-red; also beautiful lake colours, such as madder-lake. (Colouring matter, *Alizarine*, or madder-red, crystallises in yellowish-red needles, soluble in boiling water.) Madder contains, moreover, a yellow, an orange, and a brown colouring matter.

b.) *Brazil-wood* (Fernambuca), from the heart-wood of several trees growing in South America, imparts to different materials a beautiful, but not very permanent (not fast) red colour. It is employed also in the preparation of red ink, of drop-lake, &c. (Colouring matter, *Braziline*, crystallises in orange-coloured needles, easily soluble in water.)

c.) *Safflower*, the flowers of the dyer's saffron, are used for obtaining a brilliant rose-colour (for pink-saucers). (Colouring matter, *Carthamine*, soluble in water.)

d.) The *alkanet-root* contains in its bark a resinous colouring matter, which is consequently not soluble in water; cloth is dyed violet with it, but alcohol, oils (as petroleum), and fats (as lip-salve), are coloured pink with it.

e.) *Sandal-wood* (red sanders-wood), the rasped blood-red wood of a tree growing in the East Indies, contains likewise a red, resinous colouring matter (*Santaline*).

f.) The red dyes occurring in many *fruits*, as, for instance, cherries, raspberries, &c., are but slightly durable, and only used for colouring confectionery, cordials, &c.

g.) *Cochineal* is a dried insect, which is brought to us from Mexico. The well-known red carmine is obtained from it, and in dyeing establishments a very brilliant scarlet and purple red is prepared from it. (*Cochineal-red*, reddish-purple, crystalline grains.)

h.) *Lac-lake*, or *lac-dye*, is a reddish-black, resinous mass, which is obtained in the preparation of shell-lac (§ 570); it contains a red colouring matter very similar to cochineal-red.

592. *Yellow Colouring Substances.*

a.) ***Fustic*** is the rasped trunk-wood of a mulberry-tree growing in the West Indies. (*Morine*, crystallises in yellow needles, soluble in water.)

b.) ***Quercitron***, a nankeen-yellow powder, mixed with fibrous fragments, is obtained from the bark of the black oak, a tree of North America. (*Quercitrine*, a yellow powder, soluble in water.)

c.) ***Buckthorn***, ***Persian***, or ***yellow berries***, the fruit of the buckthorn, growing in warm countries, and gathered before they are ripe. (Colouring matter only known as an extract, soluble in water.)

d.) ***Weld*** and ***dyer's weed*** are the names given to the Reseda luteola, dried after it has done blooming. (*Luteoline*, crystallises in yellow needles, soluble in water.)

The four last-mentioned colouring substances are principally used for dyeing silk, wool, cotton, and other materials, yellow.

e.) ***Annotto***, ***orleana***, occurs as a brownish-red paste, which is prepared from the pulp surrounding the seeds of the Bixa Orellana, and contains two colouring principles, a yellow and a red. The former is dissolved when the annotto is boiled with water, the latter on boiling it with a weak lye. (*Orelline.*)

f.) *Turmeric*, the root of a plant growing in the East Indies, is very rich in a resinous yellow dye, which is coloured brownish-red by alkalies. Paper stained with it may therefore be used like red litmus-paper for detecting alkalies. (*Curcumine*, an amorphous yellow mass.)

g.) *Saffron* consists of the dried stigmas of the flowers of the Crocus sativus. Its application, in colouring articles of food and cordials yellow, is well enough known. (*Polychroite.*)

593. *Green Colouring Substances.*

The green matter of leaves (*chlorophyll*) is one of the most widely diffused substances in the vegetable kingdom, since it occurs in all parts of the plants which possess a green colour. As found in plants, it is a mixture of wax and of several colouring matters not well known. It need hardly be said, that it is not soluble in water; for if it were, the water would become green on flowing over meadows. The expressed juices of the herbs are indeed green, but it is obvious from their turbidness that the green matter is only mechanically mixed with the liquid. We become still more fully convinced of this by the separation of the colouring matter which takes place when the juices are boiled, or allowed to remain for some time in repose. If, on the other hand, alcohol, ether, or weak lye, is poured on the green leaves, we obtain green solutions; hence all the tinctures of pharmacy which are prepared from leaves or stalks have a green colour. The green colour appears only in those parts of the plant which are exposed to the light; it is obvious from this, that the chemical compound which we call chlorophyll is only generated with the co-operation of light. When separated from plants, this colouring matter is very soon decomposed; it is, therefore, not at all suited for a colouring substance, except, perhaps, for cordials and other liquids. In the autumn it is converted in the leaves themselves into leaf-yellow and leaf-red, probably by a process of oxidation.

Sap-green is an extract prepared from the juice of buckthorn berries, by the addition of alum.

594. *Blue Colouring Substances.*

Indigo.—Several plants of hot climates contain a colourless juice, from which, after standing in the air and abstracting oxygen from it, a blue sediment is deposited, that, when dried, forms the well-known indigo. This substance, very important to science and the arts, usually occurs in commerce in deep blue, friable cakes, which exhibit, when rubbed by the nail, a coppery colour and lustre. Its brilliant blue colouring matter is called *indigo blue;* but besides this, the crude indigo contains other foreign substances, such as indigo-gluten, indigo-brown, indigo-red.

Indigo is quite insoluble in water, alcohol, ether, &c.; there is only one liquid known which can dissolve it, fuming sulphuric acid. (§ 170.) The indigo-blue chemically combines with the sulphuric acid, forming a blue compound soluble in water, which is called *sulphindigotic acid.* What we call tincture of indigo is principally a mixture of water, sulphindigotic acid, and free sulphuric acid.

The sulphindigotic acid combines like a simple acid with bases, forming salts. The best known of these salts is *sulphindigotate of potassa* (blue carmine), which is obtained as a deep blue precipitate when the sulphindigotic acid is neutralised by potassa. The blue carmine is indeed soluble in pure water, but not in water containing a salt in solution.

Deoxidation of Indigo.—We can also, but in a very different way, render indigo soluble, by mixing it with bodies which have a very great affinity for oxygen; for instance, with protoxide of iron, protoxide of tin, &c.

Experiment.—Triturate half a drachm of finely powdered indigo, with half a drachm of green vitriol, and one drachm and a half of slaked lime; shake up the mixture in a four-ounce bottle; then, having filled the bottle with water and closed it tightly, let it stand for several days; the indigo gradually loses its blue colour, and dissolves into a clear yellowish liquid. The body which effects the decolouration is the protoxide of iron, which is separated by means of the lime from the green vitriol. This attracts oxygen from the indigo, whereby the latter becomes colourless and soluble in lime-water *(reduced indigo)*. As soon as the clear liquid is exposed to the air, it again attracts oxygen, and becomes blue. If you saturate a piece of blotting-paper with the liquid, and then dry it in the air, it first becomes green, and then blue, and the blue colour formed adheres quite firmly, since it has not only settled *upon* but *in* the fibres of the paper. In dyeing establishments, such a solution of indigo is called the *cold vat.* A third method of rendering indigo soluble is by adding it, together with hot water, to a mixture of bran, woad, madder, &c., which (carbonate of potassa and lime being present) passes into fermentation. The fermentation is partly acid, and partly putrefactive; in both processes oxygen is required, which is in part taken from the indigo. The deoxidised, colourless indigo dissolves in the alkaline liquid *(warm vat).* By treating indigo with bodies which readily part with oxygen, for instance, with nitric acid, chromic acid, &c., we have in modern times become acquainted with some very interesting products of oxidation (isatine, isatinic acid, anilic acid, picric acid, &c.).

Woad is a European plant, which likewise contains indigo, but in far less quantities than the foreign indigo plants.

Logwood, or *Campeachy-wood,* the reddish-brown interior wood of a tree of tropical America, is one of the most common colouring matters for dyeing blue, violet, and black. (*Hæmatoxyline,* in yellowish crystals, which become speedily violet and blue in the air, owing to the ammonia always contained in the latter.)

Archil.—Several species of lichens, growing on the rocks in England and France, contain peculiar substances (*orcine, erythrine,* &c.), which, although in themselves colourless, acquire a beautiful purple-red colour when they are acted upon by ammonia. It is common to putrefy the bruised lichens with urine, and then a red or violet-coloured paste is obtained (*cudbear, persio, orchil*). By the addition of lime or potassa, this red is changed into blue (*litmus*). We have examples of both these colouring matters in red and blue test-paper.

595. *Experiments with Colouring Substances.*

Experiment a.—Take up some sandal-wood on the point of a knife and put it on a filter, and pour over it some alcohol; the alcohol which passes through has a red colour, and, when poured upon a piece of wood, imparts to it an intense blood-red colour. Cabinet-makers frequently employ this solution for staining furniture. Alcohol acquires a pink colour when a small piece of *alkanet-root* is put into it. Water will not extract a red dye from either of these substances. Those colouring matters which are soluble only in alcohol are called *resinous*.

Experiment b.—Boil for some time in a jar,—1st, *yellow berries;* 2nd, *Brazil-wood;* and 3rd, *logwood;* each separately, with twelve times its amount of water; the decanted decoction of the first is yellow, of the second reddish-yellow, and of the third brownish-red; a sufficient proof that the colouring matters contained in these substances have been dissolved in the water. Dyers call these coloured decoctions *baths*.

Fig. 214.

Experiment c.—Divide these colouring decoctions into two equal parts. Dissolve a quarter of an ounce of alum in one part of each, and then add to these a solution of carbonate of potassa, as long as any precipitate subsides. As was stated in § 260, the hydrate of alumina is precipitated; but, together with this, the colouring matter is also precipitated, and hence the precipitates are coloured. These precipitates are called *lakes*. The lake obtained from the yellow berries occurs in commerce under the name of yellow lake, that from Brazil-wood as drop-lake.

Experiment d.—Prepare a solution of alum (*a*), another of salt of tin (*b*), a third of green vitriol (*c*), a fourth of carbonate of potassa (*d*), a fifth of tartaric acid (*e*), and saturate a sheet of white blotting-paper with each solution. When dry, cut each sheet into three strips, smear one of the strips from each sheet with the fustic, another of them with the Brazil-wood, and the third set with the logwood decoction, and again dry them. You will find that one and the same colouring matter produces a different colour, or shade of colour, upon each of the five sheets. This colour will be very slight when the coloured decoctions are applied to mere blotting-paper (*f*). If you now immerse the coloured and dried strips in warm water, the colours will be for the most part dissolved from the three last tests (*d*, *e*, *f*), but not from the former (*a*, *b*, *c*). Those salts which, like alum, salt of tin, and green vitriol, have the power of forming insoluble combinations with the colouring matters, and fixing them firmly in the fibres of the cloth, are called *mordants*, and are generally employed in dyeing and calico-printing establishments, to fix the dyes upon the various materials, such as silk, wool, cotton, linen, &c. That which effects the colouring is an insoluble lake colour, that is, a combination of the colouring matter with alumina, peroxide of tin, or sesquioxide of iron, but which, in order that it may adhere firmly, must first be formed *within* the pores of the vegetable fibre. If it is formed on the outside of them, it only covers the fibres externally, and then merely adheres mechanically *upon* them; such a colour may be removed from the material by rubbing, shaking, and also by washing.

The process pursued in the *printing of calico*, &c., is very similar, with this difference, however, that the mordants are only applied *in spots*, or else the whole of the cloth is first covered with the mordant, which is again removed in spots. (§ 197.) When a piece of cloth thus treated is immersed in the colouring decoction, the colouring matter will be precipitated only in those places covered with the mordant, and thus, instead of one uninterrupted uniform colour, an interrupted colour, presenting a pattern, is obtained.

XIV. ORGANIC BASES, OR VEGETABLE BASES (ALKALOIDS).

596. It has already been mentioned, under the head of extractive matter, that many plants contain peculiar substances, which, like the inorganic bases, can combine with acids, forming salts; they are called *organic bases*. Many of them, also, like the alkalies, exert a basic reaction upon *red test-paper;* hence the second name, *alkaloids*. The organic bases are to the inorganic bases what the organic acids are to the inorganic acids. The organic bases are composed of more than two, commonly of four elements (carbon, hydrogen, oxygen, and nitrogen), the inorganic of two elements only; they are charred and consumed by heat,—the inorganic bases are not; they undergo, in the presence of water and heat, a putrefactive decomposition,—the inorganic bases do not. They are characterised by containing, almost without exception, *nitrogen* in their composition.

Almost all organic bases dissolve with difficulty, or not at all, in water, but more readily in *alcohol;* their solutions have commonly a very *bitter* taste. As a general rule, they dissolve, when combined with acids as salts much more easily in water, than they do when in their simple condition.

Most of the organic bases known at present are derived from those plants which are characterised by their poisonous qualities or by their medicinal effects, and we have strong reasons for attributing to them the *poisonous* and *medicinal properties* of the plants. Many of them are virulent and dangerous poisons; but in very small doses they are energetic medicines. One grain frequently possesses the same medicinal power as an ounce, or even several ounces, of the vegetable substances from which they were obtained.

The vegetable bases, when they are dissolved, are almost without exception precipitated by *tannic acid* as nearly or entirely insoluble tannates, for which reason liquids containing tannic acid, such as tincture of gall-nuts, decoction of green tea, or of oak-bark, &c., are not only employed as tests for detecting vegetable bases, but also as effective antidotes in cases of poisoning by them.

The vegetable bases occur generally in combination with vegetable acids. They are separated from these acids, and extracted from the vegetable matter, by adding to the latter some water, and an acid which is stronger than the vegetable acid and forms with the base an easily soluble salt (muriatic acid, sulphuric acid, &c.). If an inorganic base (potassa, lime, ammonia, magnesia, &c.) is added to the acid solution, the organic base is then precipitated. But there are also numerous other methods of preparing these bases; all of them, however, are long and complicated, for the reason that many other substances are also extracted from the plants at the same time with the bases, which, in very many cases, can be separated and purified only by laborious operations.

597. Some of the most important organic bases are:

Aconitine, from the Aconitum napellus (monk's-hood), a white, granular powder, extremely poisonous; $\frac{1}{50}$ of a grain will kill a sparrow.

Atropine, from the root of the belladonna (deadly nightshade); it crystallises in white silky prisms; very poisonous.

Chelidonine, from the celandine; crystallises in colourless tables.

Quinine is found combined with kinic acid, chiefly in the crown Cinchona-bark and in the Calisaya-bark, and crystallises in silky needles; but it also occurs under the name of *quinoidine* in the amorphous state, as a dark-brown resinous mass, and is a very important medicine. The *basic sulphate of quinine*, which occurs in white needles, is most commonly used in medicine. This is very difficultly soluble in water, but is very readily dissolved in it when sufficient sulphuric acid is added to convert it into *neutral sulphate of quinine.* Another base, very similar to quinine, occurs in the grey cinchona-bark; it crystallises in white prisms, and has received the name *cinchonine.*

Caffeine, or *theine,* from the unroasted coffee-bean, or the so-called green tea; crystallises in fine white prisms of a silky lustre.

Colchicine, from meadow-saffron; crystallises in white needles; it causes, when taken, the most violent vomiting.

Daturine, from the seeds of the thorn-apple, in colourless crystals; highly poisonous.

Emetine (from ipecacuanha) occurs when pure as a white powder, when impure as a brown extract; a powerful emetic.

Hyoscyamine, from henbane, in radiated groups of white needles; a narcotic poison.

The Alkaloid of Opium. About forty years ago the first vegetable base was discovered in opium,—the inspissated juice of the poppy,—and was called *morphine.* It exists in opium combined with meconic acid, and crystallises in colourless prisms; narcotic and poisonous; in small doses, a very valuable remedy. The acetate of morphine is much used in medicine. By later investigations there have also been found in opium pseudo-morphine, narcotine, narceine, codeine, and thebaine.

Piperine, from white, black, and long pepper; in white crystalline needles.

Solanine, from several species of *solanum,* particularly from the white sprouts of the potato; as a white powder, or in crystalline, colourless needles; a narcotic poison.

Strychnine, from the nux-vomica (the seeds of the Strychnos nux-vomica), and from the Indian arrow-poison; crystallises in prisms or octahedrons; very poisonous. There is another base, *brucine,* occurring along with it.

Veratrine, from white hellebore, and the seeds of the sabadilla; a lustrous white powder, extremely poisonous; when introduced into the nostrils, it excites the most violent sneezing; $\frac{1}{16}$ of a grain will kill a cat.

The following are volatile and liquid:

Conicine, from hemlock, principally from the seeds; a colourless oily liquid, of a nauseous, strong odour; very poisonous.

Nicotine, from the leaves of the tobacco, colourless, oily, having a smell like that of tobacco. Highly poisonous; one-fourth of a drop will kill a rabbit.

Vegetable bases may also be artificially produced, for instance,—

Aniline, from indigo, or from coal-tar.

Sinammine, from oil of mustard, &c.

RETROSPECT OF THE EXTRACTIVE AND COLOURING SUBSTANCES, AND OF THE VEGETABLE BASES.

1. Besides the generally diffused vegetable substances, there occur in almost every plant *peculiar principles*, upon which, in many cases, the effect, taste, and colour of these plants depend.

2. We find these peculiar principles mixed with various other substances in the inspissated vegetable juices, the so-called *extracts*.

3. Many of them are non-nitrogenous, others nitrogenous, and still others contain at the same time sulphur.

4. Those combinations which are indifferent, and have no prominent colour, are called *extractive matters*; they are also called bitter-extractives, because they have, for the most part, a bitter taste.

5. *Colouring matters* are extractive matters, which are themselves coloured, or are converted by the action of other bodies into coloured compounds; they are quickly rendered colourless (bleached) by chlorine, slowly by light and air.

6. Colouring matters present a great affinity for some *bases*, especially for alumina, sesquioxide of iron, and peroxide of tin, and form with them insoluble coloured compounds (*lakes*); in dyeing and calico-printing these insoluble precipitates are produced in the fibres of the yarn or stuff.

7. The *vegetable bases* can, like potassa or soda, combine with acids, forming salts; many of them also exert an alkaline reaction; most of them are difficultly soluble in water, but easily soluble in alcohol.

8. The vegetable bases occur principally in those plants which are characterised by particular poisonous or medicinal qualities. Many of them are very violent poisons.

9. Almost all vegetable bases contain nitrogen.

XV. ORGANIC ACIDS.

598. The organic acids are found much more frequently, and in greater abundance, than the organic bases, in the vegetable kingdom. Several of them occur uncombined, or as acid salts; hence the acid taste which we perceive in so many vegetable substances, especially in unripe fruits. They are frequently, also, completely neutralised by bases, or are insoluble, as in the resins, and in both these cases they are not recognised by the taste. Besides these acids occurring in nature, many also have been discovered, which may be artificially produced from other non-acid vegetable substances; thus, oxalic acid and formic acid are prepared from sugar, acetic acid from alcohol, the fatty acids from fats, &c. The general properties of these acids have already been mentioned (§ 193, &c.); we shall here notice only those which are best known.

599. *Racemic acid* occurs in the juice of many grapes, and crystallises like tartaric acid, to which it is very similar, in colourless, very acid-tasted prisms.

600. *Citric acid* exists in the juice of lemons, and also in that of currants, gooseberries, and many other fruits. By evaporating the juice of the lemon, we only obtain an acid brown extract, because all the other non-volatile constituents, as well as the citric acid, remain behind; but if the juice is neutralised with chalk, a difficultly soluble citrate of lime is precipitated, while the foreign substances remain for the most part in solution. We obtain from citrate of lime, by decomposition with diluted sulphuric acid, sulphate of lime and a solution of citric acid, which yields on evaporation colourless prismatic crystals. A mixture of the pleasant acidulous-tasting citric acid (or tartaric acid) with sugar is called *lemonade-powder*. By moderate heating, the citric acid passes into *aconitic acid*, an acid which also exists in monk's-hood.

601. *Malic acid* is obtained from sour apples, the berries of the mountain-ash, and many other plants; it is very deliques-

cent, and therefore is difficult of crystallisation. Malic, citric, and tartaric acids are found associated together in almost all acid fruits.

602. *Formic acid* occurs in ants, but may be artificially produced from almost all vegetable matters, when they are treated with bodies rich in oxygen; for instance, nitric acid, chromic acid, black oxide of manganese, or sulphuric acid. It is a volatile, colourless liquid, of a very acid taste, and a very pungent odour.

603. *Tannic acid* (tannin) is the general name given to that substance, of very frequent occurrence in plants, especially in the barks of trees, which imparts to them the well-known austere and astringent taste. It is regarded as an acid, because it has an acid reaction, and can combine with bases. This acid is distinguished, according to the plants in which it occurs, as quercitannic, mimotannic, &c., acids. The *quercitannic acid*, which is found most abundantly in nut-galls and in the bark of young oak-trees, is best known. In the pure state it forms a white or yellowish gum-like mass, which is very easily dissolved in water and alcohol. It forms the principal constituent in the tincture of nut-galls. There are two properties which especially characterise tannic acid, and have stamped it as an extremely important substance in the arts:

a.) It yields, with salts of sesquioxide of iron, a *blueish-black precipitate* of tannate of sesquioxide of iron (§ 285), and therefore is generally employed for dyeing all kinds of materials with a grey or black colour, and for the preparation of ink, &c.

b.) It combines, moreover, with the skin of animals, forming a combination insoluble in water, and no longer subject to putrefaction—*leather;* hence the name *tannin*, and hence the extensive application of the vegetable substances containing tannin (bark of the oak, pine, birch trees, &c.) in the tanner's trade.

604. If a solution of tannic acid remains for a long time exposed to the air, it will be converted into two new acids, *gallic* and *ellagic acids*. Consequently, both are to be found in tincture of nut-galls, and in ink, which have been kept for some length of time. Gallic acid crystallises in white needles or prisms; its solution yields, like tannic acid, a blueish-black precipitate with salts of sesquioxide of iron, but it does not tan the skins of animals.

605. *Substances containing Tannin.*—The following are the principal dye-stuffs and tanning substances which occur in commerce.

a.) *Gall-nuts.* They are produced on oak-leaves by the puncture of an insect. The best come from Asia Minor, and contain nearly one-half of tannic acid; inferior sorts are brought from Italy and Hungary. The gall-nuts formed on trees in Germany contain but little tannic acid.

b.) *Catechu*, the brown, dry extract of the Acacia catechu, is now very frequently used in dyeing and calico-printing establishments, for the production of a brown colour; sometimes, also, for tanning skins.

c.) *Kino*, the brownish-black extract of a tree growing in the East Indies.

d.) *Sumach*, or *Rhus*, the bruised leaves of several kinds of rhus; very important in dyeing.

e.) *Divi-divi*, the seed capsules of an African plant.

f.) *Bablah*, the pods of a species of mimosa growing in the East Indies.

g.) *The rind of the pomegranate, rind of the walnut*, &c., &c.

606. The acids just mentioned, together with tartaric, oxalic, and acetic acids, previously treated of, are very widely diffused; but besides these there are many others, which are found only in particular plants or vegetable substances, or are artificially prepared from them; as—

Succinic acid, in amber; white crystals, volatile in the heat; it is formed also by the oxidation of stearic acid.

Benzoic acid, in benzoin; white crystalline needles, volatile in the heat; it is formed also in many ethereal oils, when long kept. The bitter oil of almonds, on exposure to the air, is oxidised, and completely converted into crystallised benzoic acid.

Cinnamic acid, in old oil of cinnamon and in balsam of Peru; white crystals.

Caryophyllic acid, in the oil of cloves; an oily liquid.

Valerianic acid, in the root of valerian; an oily liquid of a pungent odour. May be prepared, also, from the fusel oil of potatoes.

Suberic acid is prepared by heating cork or fatty acids with nitric acid.

Fumaric acid, in fumitory and in Iceland moss; it is formed also by heating malic acid.

Chelidonic acid, in celandine.
Meconic acid, in opium.
Kinic acid, in cinchona-bark.
Lactic acid, in whey, sour-krout, juices of flesh, &c.
Uric or *lithic acid*, in urine, &c.

XVI. INORGANIC CONSTITUENTS OF PLANTS (ASHES).

607. If we review the proximate constituents of plants treated of in the preceding section, it will be seen that they are composed either of three elements (C, H, O), or of four elements (C, H, O, N). We may accordingly regard the *organogens*, carbon, hydrogen, oxygen, and nitrogen, as the four main pillars of the vegetable world. Next to them, sulphur and phosphorus appear widely diffused in the vegetable kingdom, since they form essential constituents of the albuminous substance never failing in any plant. But the list of the chemical substances occurring in plants is not yet finished; for were it so, plants would be completely consumed by heat without anything being left behind. But on the combustion of every plant a residue remains, which neither burns away nor volatilises; consequently there must also be present, besides the combustible organic compounds, some incombustible inorganic substances. The latter are termed *ashes*.

608. The term *ashes* is just as indefinite as that of humus. *Humus* is the term generally applied to all those black or brown substances formed during the decay of organic matter; but by ashes are understood all the non-volatile and incombustible substances which remain behind after the incineration of organic matter. How very different these may be, both in quantity and quality, is obvious from even a superficial observation of the three best known kinds of ashes, those of wood, peat, and pit-coal. From a hundred pounds of wood we obtain only half a pound, or at most three pounds, of ashes; from a hundred pounds of coal or peat, twenty or thirty pounds of ashes. Wood-ashes contain very many parts soluble in water, coal and peat-ashes very few parts; the former yields with water a powerful alkaline lye, the latter does not; the former always acts on our fields and meadows as an excellent manure, the latter only in a mall degree. Great differences also appear when the ashes of

other plants or parts of plants are compared with each other, as may be seen from the following table:

	Yield	Of which are soluble in water about
100 lbs. oak-wood	2 to 4 lbs. ashes;	$\frac{1}{3}$.
100 " oak-bark	5 " 6 " "	$\frac{1}{12}$.
100 " oak-leaves (in spring)	5 " "	$\frac{1}{2}$.
100 " " (in autumn)	5½ " "	$\frac{1}{6}$.
100 " dried potatoes	8 " 9 " "	$\frac{4}{5}$.
100 " potato-tops	15 " "	$\frac{1}{15}$ to $\frac{1}{25}$.
100 " wheat-grain	2 " 3 " "	$\frac{1}{2}$.
100 " wheat-straw	4 " 6 " "	$\frac{1}{8}$ to $\frac{1}{10}$.

The quantity, as well as the nature, of the inorganic matter in plants consequently varies in the most remarkable manner, and not only according to the *difference of the plants*, but according to *the difference of the individual* parts of one and the same plant; indeed, even in the latter according to the *difference* of age. We always find the largest quantities of it in the younger vegetable organs, where the progress of growth is most active, namely, in the leaves and twigs.

609. If we ask what is the *constitution of vegetable ashes*, chemical analysis replies, that they consist principally of *potassa*, *soda*, *lime*, *magnesia*, and *sesquioxide of iron*, combined with *carbonic acid*, *silicic acid*, *phosphoric acid*, *sulphuric acid*, and *muriatic acid* (chlorine). Of these combinations there are principally,—

a.) Soluble in water, *the alkaline salts* (salts of potassa and soda).

b.) Soluble in diluted muriatic acid, *the earthy salts* (salts of lime, of magnesia, and of sesquioxide of iron).

c.) Insoluble in water and acids, *the silicates.*

The character of the prevailing inorganic constituents of a plant may be ascertained, though only in an approximative manner, by merely treating the ashes first with water, and then with diluted muriatic acid.

610. The above-named inorganic substances are often contained in the living plants in quite a different form from that in the ashes; namely, sulphur as a constituent of the albuminous matter, but the bases mostly as vegetable acid salts. That the latter are converted on ignition into carbonates (carbonate of

potassa, of soda, of lime, &c.) has previously been shown under the heads of tartrate and oxalate of potassa (§§ 194, 197), and thus is explained why almost all ashes effervesce with acids. The sulphur, on the incineration of the plant, is partly converted into sulphurous acid, which escapes, and partly into sulphuric acid, which unites with one of the bases present, and remains behind in the ashes.

611. It has already been mentioned under the heads of phosphoric and silicic acids (§§ 176, 183), and of potassa and lime (§§ 214, 240,) that these substances are able to exercise a very favourable influence upon the growth of plants, and that many plants will not flourish in a soil in which salts of potassa are wanting, and that others will not thrive in a soil which contains no lime, or no silicates or phosphates. The occurrence of inorganic substances in *all* plants must lead to the conclusion, that every plant requires a certain quantity of them for its existence, and for its complete development. If the plant does not find them in the soil assigned to it, it is obstructed in its growth; it pines and withers away before attaining maturity. It is highly probable that basic bodies, as lime and potassa, act here in a predisposing manner, similar to that in the formation of nitric acid; that they occasion by their presence the formation of organic acids, with which they afterwards enter into combination. On the further growth and ripening of the plants, there are formed, as it appears, from these acids, the indifferent substances starch, sugar, gum, &c.; for, as is well known, the acid taste is lost in many vegetable parts, especially in the fruits at the time of ripening, while a mealy, sweet, or mucilaginous taste supplies its place.

It follows from what has previously been stated, that the inorganic salts requisite for the growth of each individual plant may be ascertained most simply by burning the plant, and examining the ashes which remain; *it requires the same substances which are found in its ashes.* If we now examine the soil on which plants of this kind are to be cultivated, we shall find by comparison which of the constituents of the ashes are already present in it, and what constituents must be added to it that the plants may find therein all the mineral substances requisite for their development and growth.

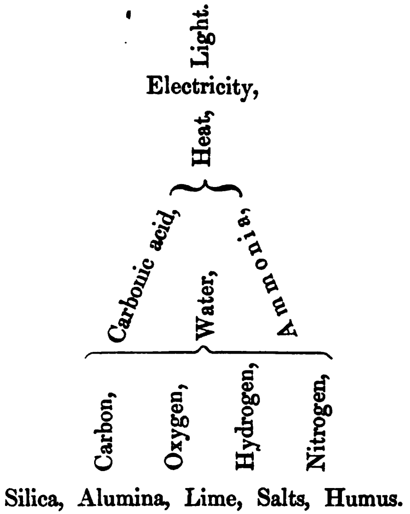
612. The *Soil*, that is, the upper thin layer of the surface of our earth, in which plants germinate and take root, con-

sists chiefly of two different kinds of matter; namely, *inorganic* substances, belonging to the mineral kingdom (silica, combinations of silicic, phosphoric, carbonic, and sulphuric acids with alumina, lime, magnesia, potassa, soda, and iron), and *organic* substances, derived from the animal and vegetable kingdom (humus-like substances).

The ground and soil which are adapted to vegetation are principally formed of *mineral substances*, more or less finely divided, which consist of rocks that have been disintegrated by the operation of the atmosphere, or weathered, during the lapse of centuries. (§ 265.) This weathering is going on uninterruptedly, even now, in the soil of the earth, and so much the more rapidly in proportion as the soil is loosened and penetrated by air and water (fallow). But during this process, the masses of rock are not merely mechanically broken into small fragments, but they are also chemically changed, since from their several insoluble constituents, soluble salts—for instance, salts of potassa, soda, lime, &c.—are generated, which may be absorbed by the roots of the plants. Everything which promotes the weathering and dissolution of the rocks—for instance, burning the soil (§ 258), mixing it with lime (§ 240) or acids (§§ 173, 186, &c.)—will accordingly, as a general rule, exercise a beneficial influence upon the growth of plants.

The *organic substances* contained in the soil have always a brown or black colour, and are designated by the general term *humus*. (§ 444.) They partly consist of decaying leaves and branches, which have fallen off, and of decaying roots of plants remaining behind in the earth, and partly of decomposing vegetable or animal manure put upon the soil. It has already been previously mentioned, that these products of decay are gradually still further decomposed into carbonic acid, ammonia, and water, and for this reason cause a more vigorous growth of the plant. They likewise act favourably on vegetation, because by reason of their dark colour the soil is heated more strongly by the rays of the sun, because they loosen the soil, and finally, because the weathering of the rocks is promoted by the carbonic acid which is set free from them.

XVII. NOURISHMENT AND GROWTH OF PLANTS.



613. *Carbon*, *oxygen*, *hydrogen*, and *nitrogen*,—these are the four elements which the Divine Power has established as main pillars for the structure of the whole organic creation; from them, and also from *sulphur*, *phosphorus*, and some other inorganic substances, all the numberless wonderful forms of the animal and vegetable world are produced. We as yet know but little about the true chemical process by which these results are effected, but we have nearly ascertained the external conditions under which they take place, and the sources from which the above-named elementary substances are derived.

That plants require for their germination and development *soil*, *water*, *air*, *heat*, and *light*—those universal conditions of vegetable life—is well enough known; but the chemical investigations of modern times only, and particularly those instituted by Liebig, have diffused a clearer light as to what individual constituents are taken up from the earth, the water, and the air by the plants, and serve them as means of nourishment.

WILD PLANTS (MEADOWS, FORESTS, &c.).

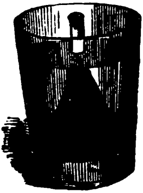
614. *Food of Plants.*—Plants absorb their nourishment partly by the roots, partly by the leaves. It follows from this, that the nourishment must either be liquid or aeriform; for in these two forms only can it penetrate into the fine pores of the root-fibres and leaves. Plants receive their hydrogen and oxygen from the *water*, their carbon from *carbonic acid*, their nitrogen principally from *ammonia*, their inorganic constituents chiefly from the *earth*. Water, carbonic acid, ammonia, and a small number of inorganic salts, are accordingly to be regarded as the nourishment of plants.

a.) *Water furnishes the plants with oxygen and hydrogen.*—The plants imbibe it as a liquid, by their roots, from the earth, and as vapour, through their leaves, from the air. Water is, moreover, essential to plants, in so far as it occasions, by its fluid condition, the formation of the solid vegetable parts; for all the solid ingredients of the plants are developed from the juice, which is rendered liquid by water.

b.) *Carbonic acid furnishes the plants with carbon.*—This is *principally* absorbed (§ 167) by the leaves from the air, which is constantly supplied with it by processes of combustion, decay, and respiration. Moreover, the roots of the plants find carbonic acid in every soil which contains humus, for humus consists of decaying organic matter, that is, organic matter resolving itself into carbonic acid and water. (§ 444.) From this limited source the young plants especially draw their nourishment, before they have leaves enough by means of which to appropriate to themselves the carbonic acid from the free air. The changes which the latter undergoes by the action of living plants are shown in the following experiments:

Experiment.—Fill a glass funnel with the fresh leaves of some plant, and invert it in a wide glass vessel filled with water, in such a manner as quite to cover the funnel with water. Now close the upper opening of the funnel with a cork, suck out, by means of a glass tube, a part of the exterior water, and expose the vessel to the sun; bubbles of air will soon rise from the leaves, and collect in the tube of the funnel. When the water is so far pressed down within the funnel that it stands on a level with the exterior water, then uncork the fun-

Fig. 215.



nel, and hold a glowing shaving in the gas evolved from the leaves; the shaving will inflame briskly, just as it would in oxygen gas. Indeed, this gas is really oxygen, which is derived from the carbonic acid contained in the water. Thus, in the plants, the carbonic acid has been resolved into its constituent parts, by the influence of light; its oxygen becomes free, and escapes, but its carbon remains behind in the plants. *Plants inhale carbonic acid, and in the light exhale oxygen.*

Experiment.—Repeat the experiment, but with this alteration,—pour, instead of common water, Selters water over the leaves; this contains a greater abundance of carbonic acid, and the consequence is, that the evolution of oxygen gas proceeds more briskly, and continues longer.

Plants consist principally of vegetable tissue, starch, gum, mucus, sugar, &c., each composed of three elements; all these may be produced from carbonic acid ($C\,O_2$) and water ($H\,O$), when the elements of the water combine with the carbon of the carbonic acid. If this happens, the oxygen of the latter must necessarily be liberated. From

$$\begin{array}{llll}
\text{Carbonic acid} = & & \text{Carbon,} & \text{Oxygen,} \\
\text{and Water} \;\; = & \text{Hydrogen, Oxygen,} & & \\
\text{are formed} & \multicolumn{2}{l}{\underbrace{\text{Hydrogen, Oxygen, Carbon}}_{\text{Vegetable tissue, starch, mucus, sugar, \&c.}}} & + \underset{\text{(is liberated.)}}{\text{Oxygen}}
\end{array}$$

It is also, perhaps, possible that the elements of the carbonic acid combine with the hydrogen of the water, and that accordingly the oxygen which becomes free is derived from the water; the chemical process would then be different from that just stated, but the results would be exactly the same. From

$$\begin{array}{llll}
\text{Water,} \qquad\qquad\;\; = & & \text{Hydrogen,} & \text{Oxygen,} \\
\text{and Carbonic acid} = & \text{Carbon, Oxygen,} & & \\
\text{are formed} & \multicolumn{2}{l}{\underbrace{\text{Carbon, Oxygen, Hydrogen}}_{\text{Vegetable tissue, starch, mucus, sugar, \&c.}}} & + \underset{\text{(is liberated).}}{\text{Oxygen}}
\end{array}$$

c.) Ammonia furnishes plants with nitrogen.—When vegetable and animal matters decay, ammonia ($N\,H_3$) is formed from their nitrogen, carbonic acid from their carbon; both of these products combine with each other, forming a volatile salt which escapes in the air. It is condensed again from the air, partly by the loam or clay (§ 256) and the humus of the soil (§ 444), partly by the dew, rain, and snow, and returned again to the earth, and then with the water absorbed by the plants. If organic substances decay in the soil where plants are growing, the ammoniacal salt is, immediately after its formation, absorbed by their roots. Whether ammonia can be formed *directly* from the nitrogen of the air, where the latter is in contact with decaying substances in moist earth, and can be of service to the plants, has not yet been ascertained with certainty; whereas it may be regarded as proved that plants have the power of withdrawing nitrogen even from nitrates when these are present in the soil.

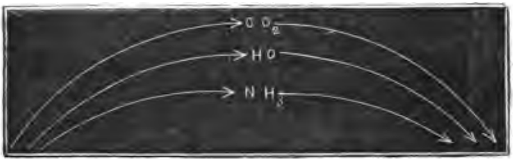
In what manner the assimilation of ammonia takes place in the vegetable kingdom is, indeed, not yet known, but it is probably the ammonia from which plants take the nitrogen requisite for the formation of their nitrogenous constituents, such as albumen, gluten, caseine, organic bases, &c. From

Carbonic acid = Carbon, Oxygen,
Water = Hydrogen, Oxygen,
Ammonia = Nitrogen, Hydrogen,
are formed

$$\underbrace{\text{Nitrogen, Hydrogen, Oxygen, Carbon}}_{\text{Albumen, gluten, caseine, organic bases, \&c.}} + \underset{\text{(is liberated).}}{\text{Oxygen}}$$

Carbonic acid, *water*, and *ammonia*, accordingly contain in their elements the essential constituents for the formation of all vegetable substances (carbon, hydrogen, oxygen, and nitrogen). On decay and putrefaction, animal and vegetable matter is decomposed into carbonic acid, water, and ammonia. What seems to us to be destruction is, however, only conversion; the form only passes away, the matter itself is unchangeable. From the disgusting substances of decay are formed again the living wonders of the vegetable world.

Fig. 216.



d.) ***Plants are furnished, through the soil and water, with the requisite inorganic matters.***—The soil is constantly undergoing changes; the organic matter contained in it decays, the inorganic is decomposed by the action of time and weather. By the last agents soluble salts are always forming from insoluble rocks, which salts may now be absorbed by the roots of plants. Weathering takes place also beneath the surface of the earth, and indeed wherever air and water can penetrate into the mass of rocks. The substances thus rendered soluble are taken up by the rain-water, and constitute the salts contained in our common spring and river waters; accordingly, in many places plants can receive inorganic matter from water also. Finally, the air likewise contains inorganic substances which have been conveyed into it by evaporation (§ 182), especially from the ocean, and also by the force of the winds, and which are diffused by it over the whole earth. These are returned again to the earth in rain, dew, snow, &c., and thus we can no longer wonder at finding in plants salts (for instance, common salt) not existing in the rocks from which the soil serving as a habitation for these plants has been formed. The changes which these substances undergo in living plants have already been noticed in the preceding section.

It should still be expressly stated, that a plant can grow vigorously, thrive, and attain complete maturity, only when the substances mentioned at *a*, *b*, *c*, and *d* are *all four* presented to it *simultaneously*. As the life of man ceases if only a single condition necessary for his continued existence is withdrawn, for instance, the air (oxygen), or water,—as a clock stops if only a single wheel is taken from it,—so also the complete development of a plant is obstructed when one of the abovementioned means of nourishment fails.

CULTIVATED PLANTS.

615. If we give abundant and invigorating food to an animal, it becomes vigorous and fat; on scanty and slightly nourishing food, it remains poor and lean. Just the same thing occurs also with plants. When they find an abundance of all the substances which they require for their development in the soil and in the air, they will grow up more vigorously, and put forth more branches, leaves, flowers, and fruits, than when they do not find these substances, or find only a part of them, in sufficient quantity. Consequently, the way of obtaining from our fields and meadows the largest produce, consists in presenting to the plants which are to be cultivated upon them *all* the

materials requisite for their nourishment in *sufficient* quantity. We do this by *manuring* the soil.

616. Nature, by means of rain and dew, decay and putrefaction, provides that the three universal means of nourishment, water, carbonic acid, and ammonia, shall not be wanting to plants; and man also, without exactly intending it, contributes his share by the act of breathing and by the fires he kindles. The air contains an inexhaustible supply of these substances, since the processes by which they are generated on the earth never suffer an intermission. The air alone would accordingly suffice for the nourishment of plants, if they could only find in the soil the necessary inorganic salts in solution. But as a structure advances more rapidly when it is worked upon at several parts at the same time, so the growth of a plant proceeds *more rapidly and more luxuriantly* when it can take up nourishment from several different sources, not only by the leaves, but at the same time also by the roots. All vegetable and animal substances are converted by decay into water, carbonic acid, and ammonia; hence it is quite natural that such substances, when they decay in a moist soil, should promote the growth of the plants sown in that soil. Hereby is explained, *but in part only*, the beneficial influence exerted upon vegetation by the universally used animal and vegetable manures, as, for instance, the so-called humus-like substances formed from excrements, urine, horn-shavings, bone-dust, guano, straw, leaves, &c.

617. But the reception of these universal means of nourishment, and their transformation into organic matter by the vital activity of the plants, can, as already mentioned, only take place by the aid of the *inorganic salts*. If these are wanting in a soil, the seeds sown in it may indeed germinate and grow for a while, because they contain within themselves a certain quantity of those inorganic constituents which the plants require for their growth, but the growth will cease when the constituents are exhausted in the development of the young plants. Nature provides, indeed, for the formation of soluble substances in the earth, by the gradual action of the weather; but these are not sufficient to yield a rich harvest year after year from the same fields, and it is therefore indispensable to mix these constituents artificially with the soil in order to maintain its fertility. This is done, either *directly by those mineral sub-*

stances which contain lime, potassa, soda, phosphoric acid, &c., as, for instance, by lime, gypsum, marl, wood-ashes, bone-ashes, animal charcoal, common salt, &c.; by the overflowing of meadows with water, &c.; or *indirectly, by the salts contained in most kinds of manure*. The soluble salts existing in the food are removed again from the animal body by the urine of animals, the insoluble by the solid excrements; and thus is explained, in a simple manner, why the excrements of animals fed upon oats are the most appropriate and most powerful manure for oats; those of animals fed upon peas, clover, or potatoes, the best manure for peas, clover, or potatoes. In these saline or inorganic substances lies the *second mode* of operation of the animal and vegetable manures.

Since *different* kinds of plants require *different* inorganic substances, and *different quantities* of them, for their nourishment,—some, for instance, principally salts of potassa, others salts of lime, and others again phosphates or silicates,—so it is advantageous in the cultivation of plants to make such an *alternation (rotation of crops)* that a potassa plant shall be followed by a lime plant, and this again by a silica plant, &c. In this way, it is possible to obtain from a field which is exhausted for one kind of plant a second or a third crop consisting of a different species of plant, without the necessity of manuring it each time.

618. It is clear from these hints, that chemistry alone can give to the farmer a knowledge of the constituents of his soil, of the constituents of the plants which he wishes to cultivate upon this soil, and of the substances which must be added to it in order that the plants may find there all that is necessary for their nourishment. Inducement enough is hereby offered to every farmer to cultivate a more intimate acquaintance with this science, as the only guide to be relied upon in his practical experiments and occupations.

RETROSPECT OF VEGETABLE MATTER IN GENERAL.

1. WHILE a plant lives, a constant motion, and a constant reception, change, and evolution of certain aeriform and liquid substances, are continually taking place in it. If these substances

are wanting to the plant, its growth and life cease; we therefore regard them as food for the plant.

2. These substances all belong to the inorganic compounds; they consist,—

a.) Of a combination of hydrogen and oxygen (water).

b.) Of a combination of carbon and oxygen (carbonic acid).

c.) Of a combination of nitrogen and hydrogen (ammonia).

d.) Of inorganic acids and bases (salts).

3. From these substances are formed, in an incomprehensible manner, the juices of the plants, and from these the individual parts of the plants (organs), together with the innumerable vegetable substances which we find in them.

4. The vegetable substances may be classified by different methods. We may classify them,—

I. According to their *more or less general diffusion:*

a). Into such as occur in almost *all* plants; for instance, vegetable tissue, starch, sugar, gum, mucus, fats, many acids, chlorophyll, albuminous matter, &c.

b.) Into such as occur only in *certain* kinds of plants; for instance, extractive matter, colouring matter, volatile oils, resins, many acids, organic bases, &c.

II. According to their *chemical character:*

a.) Into vegetable acids.

b.) Into vegetable bases.

c.) Into indifferent vegetable matter.

The *indifferent* combinations predominate in the vegetable and animal kingdoms, the acids and bases in the mineral kingdom.

III. According to ther *composition:*

a.) Into *non-nitrogenous* substances, and these:

- *α.* into those rich in oxygen, namely, organic acids, &c.
- *β.* into those rich in hydrogen, namely, fats, volatile oils, resins, &c.;
- *γ.* into those rich in carbon, namely, vegetable tissue, starch, sugar, gum, mucus, &c.

b.) Into *nitrogenous* substances; for instance, organic bases, many of the colouring matters, &c.

c.) Into those *containing nitrogen and sulphur;* for instance, albumen, gluten, caseine, &c.

The *non-nitrogenised* compounds predominate in the vegetable kingdom, the *nitrogenised* and *sulphurised* compounds in the animal kingdom.

5. The vegetable substances produced by nature may be transformed and decomposed in various ways into new combinations. They may be *changed*,—

a.) By *the addition of oxygen*; as,

α. by combustion with free access of air (carbonic acid, water, nitrogen);

β. by decay (humus, carbonic acid, water, ammonia, acidification of spirituous liquids, and of other vegetable substances; grass-bleaching, &c.);

γ. by mere exposure to the air (drying or becoming rancid of fats, conversion into resin of the volatile oils, &c.);

δ. by evaporation (the becoming brown of extracts, &c.);

ε. by the action of nitric acid, chromic acid, and other bodies rich in oxygen (conversion of sugar into saccharic acid, oxalic acid, &c.).

b.) By the *abstraction of oxygen* (reduction of indigo-blue).

c.) By the *abstraction of hydrogen* (bleaching with chlorine).

d.) By *combining with sulphurous acid* (bleaching with this acid).

e.) By the *abstraction of hydrogen and oxygen* (transformation of alcohol into ether or olefiant gas, and also of oxalic acid into carbonic oxide and carbonic acid by sulphuric acid; carbonisation of wood by sulphuric acid, &c.).

f.) By the *addition of hydrogen and oxygen* (putrefaction of vegetable matter with exclusion of air, as, for instance, under water; that is, the conversion of vegetable matter into carbonic acid, carburetted hydrogen [marsh gas], water, ammonia, mud, peat, brown-coal, pit-coal; conversion of starch or sugar into lactic acid, &c.).

g.) By *heating with exclusion of air* (charring or dry distillation of wood, of coal, of the fats, of the acids, &c., that is, their conversion into carbonic acid, carburetted hydrogen [illuminating gas], water, wood-vinegar [empyreumatic acids], ammonia, tar [burnt oil, burnt resin], creosote, wood-charcoal, coke, &c.).

h.) By the peculiar action, not yet thoroughly investigated, of an easily decomposed body or *ferment* (vinous fermentation, that is, decomposition of sugar into alcohol and carbonic acid).

i.) By the *transposition*, not yet explained, of one vegetable substance into another *isomeric* (equally constituted) compound; for example,—

- *a.* conversion of starch into gum and sugar by sulphuric acid;
- *β.* conversion of starch into gum and sugar by diastase;
- *γ.* conversion of starch into gum by moderate heating;
- *δ.* conversion of cane sugar into liquid sugar by heating or long boiling with water;
- *ε.* coagulation of albumen by heating, &c.

k.) By the *operation of strong bases* upon vegetable matter; for example,—

- *a.* formation of cyanogen (§ 291);
- *β.* formation of ammonia (§ 232);
- *γ.* formation of nitre (§ 207);
- *δ.* formation of soap from fats (§ 540).

l. By the action of light (formation of chlorophyll, bleaching of colours, &c.).

These are only a few of the more important metamorphoses of vegetable matter as yet known to us; but their extent is unlimited, and increases every day, since extraordinary industry and zeal are now devoted to the investigation of this particular department of chemistry.

ANIMAL MATTER.

619. The chemical processes which take place in the living *animal* are far more mysterious and more complex than even those which take place in plants. That such actions really do occur in the animal body, who can doubt? We here see that which peculiarly characterises these processes, the conversion of bodies into new bodies with entirely new properties, far more distinctly and more forcibly than in plants and minerals. For can there be a more striking metamorphosis than that of the constituents of the egg (albumen, yolk, and egg-shell) into the constituents of the young bird (flesh, blood, bones, feathers, &c.)? or the conversion of milk, which constitutes the sole nourishment of many young animals, into flesh, blood, &c.? That chemical force alone cannot effect these changes has already been stated in the earlier part of this work; it is merely

the instrument, the means, which the Divine Power has employed, in a way as yet concealed from us, to form, *during the life* of the vegetables and animals, all the different parts of the vegetable and animal kingdom. That which principally distinguishes animal life from vegetable life is, that during the former, oxygen is incessantly *inhaled*, but during the latter it is *exhaled;* and also, that, with the exception of water and some salts, organic substances only are appropriated to the support of the former.

620. The chief mass of vegetable matter consists of non-nitrogenous substances, consequently of substances which contain only three elements; but in the animal body, on the contrary, the *nitrogenous* and *sulphurised substances* (albuminous substances), consequently far more complex combinations, predominate. Water and fat are almost the only substances, composed of only two or three elements, that occur in the animal body; all the others, for instance, flesh, cartilage, blood, hair, nails, &c., are rich in nitrogen, sulphur, and also in phosphorus. It is also characteristic of these substances that they do not assume a crystalline form; we find crystalline combinations—as, for instance, in urine (urea, uric acid, &c.)—in those animal liquids only, which, being unfit for assimilation, are again separated from the body. Most animal substances, when viewed under the microscope, exhibit the form of small globules. Accordingly, the globular form is the fundamental form for the composite, more highly organised types of the animal kingdom, while in the more simple, lifeless productions of the mineral kingdom, the angular form (crystalline form) prevails. In the vegetable kingdom, holding an intermediate position between the two, we find both forms, namely, the globular or spherical in starch, yeast, &c.; the crystalline in sugar, in organic acids, bases, &c.

621. The elementary matter from which the proximate constituents, and from which again the organs of the animal body, are formed, is exactly the same as that which occurs in the vegetable kingdom, namely, *oxygen*, *hydrogen*, *carbon*, *nitrogen*, *sulphur*, *phosphorus*, and *chlorine;* and the metallic substances, *lime*, *potassium*, *sodium*, and *iron*. These must be introduced into the animal body in order that it may grow and live. How this happens may be shown most simply in the constitution of the *egg* and of *milk*.

I. THE EGG.

The egg, as is known, consists of the *albumen*, the *yolk*, and the *shell*.

622. *Albumen.*—The *white* in the hen's egg consists of cells, in which is contained a colourless alkaline liquid, the *albumen*. On evaporation, we obtain from it one-eighth of solid albumen; the rest is water. When burnt, it leaves behind common salt, carbonate, phosphate, and sulphate of soda, and phosphate of lime. That albumen, when briskly beaten up, yields a porous light froth, that it becomes insoluble and coagulates by heating, &c., are well known facts. On account of the latter property, it is used for clarifying turbid liquids, especially saccharine juices.

Experiment.—Stir up some honey in warm water, add a little albumen to the turbid solution obtained, and heat the mixture to boiling. The albumen seizes upon the foreign substances floating in the liquid, bears them to the surface, and incloses them within itself as it coagulates; the liquid thereby becomes clear and transparent, and may be separated by a strainer from the coagulated albumen.

The constituents of animal albumen are just the same as those of vegetable albumen. (§ 477.)

623. The *yolk of eggs* consists of albumen holding in suspension yellow drops of oil. On account of the albumen contained in it, it coagulates when heated, and the fat *(oil of the yolk of eggs)* may be extracted from it by strong pressure, or by agitation with ether. *Phosphorus* is contained in the oil of yolk of eggs.

624. *Egg-shells.*—*Experiment.*—Pour some diluted muriatic acid upon some egg-shells; with the exception of some membrane, they will entirely dissolve, with the evolution of gas. The gas which escapes is carbonic acid; but lime is contained in solution in the muriatic acid, as we may ascertain by the addition of sulphuric acid, which throws down sulphate of lime from it. The shells have accordingly the same constitution as chalk,—namely, they consist of *carbonate of lime.*

There are in the egg-shells small pores, through which the air penetrates into the interior of the egg, and gradually effects a change (putrefaction) of the latter. If these openings are stopped up,—for instance, by packing the eggs in ashes, or by smearing them with oil,—the eggs will keep much longer unchanged, as the penetration of the air is thus prevented.

II. MILK.

Milk consists of a solution of *caseine* and *sugar of milk* in water, in which solution small *globules of oil* are held suspended. The latter render the milk opaque, and give it the appearance of an emulsion.

625. *The Oil-Globules.—Experiment.*— These globules cannot be separated from the milk by filtration alone, as they are so small that they pass with it through the pores of the finest paper; but it may be accomplished in the following manner. Dissolve an ounce of Glauber salts and a couple of grains of carbonate of soda in half an ounce of lukewarm water, and agitate the solution with half an ounce of fresh milk. If you now transfer this mixture to a filter, the fatty portions (cream) remain behind, while a liquid, only slightly opalescent, passes through. The saline solution added does not act chemically upon the constituents of the milk, but it only acts mechanically, causing the globules to form a more compact mass, and to be more readily separated from the watery liquid.

626. *Caseine.—Experiment.*—If you add to the filtered liquid a few drops of muriatic acid, the *caseine* separates from it as a white flaky mass; accordingly, the animal caseine is likewise coagulated and rendered insoluble by acids in the same manner as vegetable caseine (§ 452), with which it exactly agrees in constitution. Pure caseine is insoluble in water, but it dissolves in it when alkalies are present; these always exist in the milk, and keep the caseine in solution. The alkali (soda) is withdrawn from the caseine by the acids which are added, and the caseine then separates in the familiar form of new cheese. Caseine is an albuminous substance, that is, it contains, besides carbon, hydrogen, and oxygen, also some *nitrogen* and *sulphur* in its constitution.

627. *Albumen.—Experiment.*—If you filter the caseine from the liquid, and then boil the latter, it again becomes turbid, although less so than before. It is the *albumen* which separates, small quantities of it being present in all milk.

628. *Experiment.*—Let a small piece of the dried membrane of the stomach of a calf (*rennet*) remain standing one night in a spoonful of water, and afterwards pour this water upon a quart of new milk; the milk, after having stood for some hours in a warm place, will coagulate into a gelatinous mass, which is to be put upon a filter. What remains behind consists of an

intimate mixture of the curdled *caseine with globules of fat.* By pressing and drying, we obtain from it the so-called *cream-* or *new-milk cheese* (Swiss, Dutch, Cheshire, &c., cheese).

629. *Sugar of Milk.—Experiment.*—Separate the filtered liquid (*sweet whey*) from its albumen by boiling, and, having again filtered it, evaporate until only a few ounces of it remain. If left in a warm place, hard, prismatic white crystals of *sugar of milk* will be deposited. (§ 473.) By this method sugar of milk is procured in Switzerland on a large scale. Consequently the sweet whey is to be regarded principally as a solution of sugar of milk (together with some albumen and some salts) in water.

Experiment.—Dissolve again in water the sugar of milk obtained, and put a piece of *rennet* in the solution; the liquid will soon become sour in a warm place, because the sugar of milk is converted into *lactic acid.*

630. *Experiment.*—The coagulation of the milk, which was produced by the rennet in a few hours, is effected instantaneously by the addition of *acids*, as is rendered obvious by adding a few drops of some acid to heated milk. In this curdled mass are contained all the caseine and fatty particles of the milk (cheese and butter).

631. *Experiment.*—Fill a bottle with fresh milk, close it, and keep it, inverted, from twenty-four to thirty-six hours in a cool place; then loosen the stopper a little, so that the lower, thinner portion of the milk (*blue* or *skim milk*) may run off, but the upper, thicker part (*cream*) remain behind. On standing, the lighter oil-globules of the milk ascend, and form on the surface the well-known fatty, thick cream. If this is shaken for some time, the membranes of the oil-globules are torn, and the latter then unite together, forming masses of butter. The thin milk which passes off from beneath may be separated, in the way already described, into caseine, albumen, and sugar of milk.

Butter, like the vegetable fats, consists of a solid fat (*margarine*) and a fluid (*oleine*), and it has also exactly the same properties. (§ 533.) But besides these two kinds of fat, butter contains a small quantity of a peculiar fat (*butyrine*). If butter remains exposed some time to the air, some volatile fat acids having a disagreeable smell and taste will be generated in it; these cause the rancidity of butter. If butter that has become rancid is boiled several times with double its quantity of water, these acids will be removed from it, and the butter, on cooling, will have regained its agreeable flavour.

632. If you let milk stand for some time in *open vessels*, its sugar of milk is gradually converted into *lactic acid*, and this, like every other acid, causes a curdling of the milk, and at the same time, its well-known sour taste. But the curdling first commences after most of the oil-globules have collected on the surface (sour cream). From this cream, butter is most usually prepared with us, and therefore the buttermilk remaining (a mixture of curdled caseine, lactic acid, and water, with some particles of butter remaining behind) has an acid taste. The so-called *curd* beneath the cream now contains only traces of fat, and consists accordingly of water, lactic acid, and coagulated caseine. By pressing we obtain from it the *sour whey*, and, as a residuum, the coagulated caseine, from which our common *skim-milk cheese* is made. When kept damp this undergoes a decomposition (putrefaction), by which ammonia is generated, which forms with the caseine a soft saponaceous mass. If the putrefaction advances still farther, there will be finally generated also volatile compounds of a very offensive odour (sulphuretted hydrogen, volatile fatty acids, &c.).

633. *Fermentation of Milk.*—*Experiment.*—Let milk stand in a bottle till it begins to curdle, and then put the bottle furnished with a tube for the evolution of gas (Fig. 188) in a place the temperature of which ranges from 75° F. (24° C.) to 86° F. (30° C.) A brisk ebullition of carbonic acid will commence, because the sugar of milk, which has not yet passed into lactic acid, is converted, at a higher temperature, first into grape sugar, and then into alcohol and carbonic acid. But there is also formed at the same time some butyric acid, which imparts a disagreeable taste to the spirit, obtained by the distillation of the fermented liquid after it has been strained and squeezed off. The *koumiss* prepared by the Calmucs is a liquor obtained by the fermentation of mare's milk.

634. *Ashes of Milk.*—If milk is burnt with access of air, there remain behind, after all its carbon, hydrogen, oxygen, and nitrogen have been converted into aeriform combination, *ashes*, which consist of potassa, soda, lime, magnesia, and sesquioxide of iron, and also of phosphoric acid, sulphuric acid, and chlorine.

635. *Digestion.*—If we reconsider the constituents of the egg and the milk, as just stated, we find in them the following elementary substances:

The egg consists of		Milk consists of	
Water	= H, O.	Water	= H, O.
Oil of eggs	= H, O, C, P.	Butter Sugar of milk	= H, O, C.
Albumen	= H, O, C, N, S, P.	Caseine Albumen	= H, O, C, N, S, P.
Shell and other inorganic substances	Ca, Na, K, Fe, P, S, Cl, O.	Inorganic substances	= Ca, Na, K, Mg, Fe, P, S, Cl, O.

But exactly the same, and the same only, elementary substances are found also in the animal body; accordingly, it must be concluded that the constituents of the hen's egg are used, in the hatching of the egg, for the development of the young chicken, and the constituents of the milk which forms the food of the young mammalia are used for the growth and nourishment of the latter. It is the same, also, with the constituents of the vegetable and animal substances, which serve us as *food.* The food is mixed up in the stomach with the *gastric juice* (a liquid containing free *muriatic acid* and common salt, which liquid is secreted by the inner skin of the stomach,—*mucous membrane*), and is thereby softened into a soluble, white, pulpy, mass (chyme). The muriatic acid is likewise formed by a decomposition of common salt taking place in the body, and it is indispensable for the solution (digestion) of the food. The explanation of this action is, that water, rendered feebly acid by muriatic acid, is able (after it has been previously left in contact for a day with a piece of rennet) to dissolve, at a temperature of from 86° F. (30° C.) to 104° F. (40° C.), hard-boiled albumen, flesh, and other food. All of the chyme which has become soluble is, during its passage through the intestines, absorbed and introduced as nourishment (chyle) into the blood. The changes which the food experiences in the animal body are therefore the following: from the food is formed chyme, from this chyle, from this blood, and from the blood all the numerous organs and parts of the animal body are generated, just as all the organs and parts of plants are generated from the vegetable sap.

III. THE BLOOD.

Like milk, the blood also consists of a liquid as clear as water, in which small globules are held suspended; but these globules (blood corpuscles) have, however, a yellowish-red colour.

636. *Experiment.*—If you let the blood of an animal remain standing quietly in a vessel, it will, in a short time, undergo a change; it coagulates, forming a dark-red jelly (*clot, coagulum*), which contracts on longer standing, and a yellowish liquid is separated (*serum*). When the latter is heated to boiling, it coagulates to a white jelly; the serum consists of a solution of *albumen.* There are two substances combined together in the coagulum, one of which dissolves by long washing in water, communicating to it a red colour (*colouring matter of the blood,* the principal constituent of the blood corpuscles), while the other remains behind as a white fibrous mass (*animal fibrine*). Accordingly, the most important proximate constituents of the blood are water, albumen, blood corpuscles, and animal fibrine, which, on the standing of the blood, are transposed in the following manner:

$$\begin{array}{cccc} \text{From} & \underbrace{\text{Water, Albumen,}} & & \underbrace{\text{Blood Corpuscles, Fibrine,}} \\ \text{are formed} & \text{Serum} & \text{and} & \text{Coagulum.} \end{array}$$

It is a distinguishing peculiarity of the colouring matter of the blood, that it always contains iron.

637. *Experiment.*—If the blood freshly drawn from the veins is beaten up during cooling, it does not coagulate; the *fibrine* certainly becomes also insoluble, but exists as a thread-like coherent mass, which, when kneaded for some time with water, becomes finally white, and, after drying, resembles the muscular fibre. Indeed, it may be regarded as half-formed flesh, since it has entirely the same composition, and the flesh of the animal body is formed from it. The blood remaining behind retains, after the separation of the fibrine, its red colour, and coagulates on boiling to a jelly of a dark-red colour, as may be perceived in the so-called *black-puddings.* The metamorphosis of the blood just treated of is, accordingly, as follows:

$$\begin{array}{cc} \underbrace{\text{Water, Albumen, Blood Corpuscles}} & \text{Fibrine} \\ \text{remain liquid.} & \text{becomes solid.} \end{array}$$

Fibrine belongs to the albuminous substances; it is very rich in nitrogen, and contains also sulphur and phosphorus in organic combination.

638. *The Ashes of Blood.*—If blood is evaporated to dryness, and heated for a long time in the air, it will finally burn away, with the exception of some ashes. These ashes consist of alkaline phosphates (much soda, little potassa), phosphates of

the alkaline earths (lime, magnesia), phosphate of the sesquioxide of iron, common salt, and the alkaline sulphates; consequently of the same constituents which we find in the ashes of our principal articles of food (eggs, milk, bread, &c.). In the vegetable kingdom we find these ash-constituents most abundant in those vegetable parts which are rich in albuminous matter, especially in the seeds of our corn and leguminous plants.

639. *Respiration and Food.*—As long as an animal lives, its blood is in a state of constant motion and of constant change. Light-red blood streams out from the heart, through the arteries, into all parts of the body, from which it returns, darker coloured, through the veins, back again to the heart. But before the latter blood recommences its circulation, it is propelled through the lungs, in which it comes in immediate contact with the inhaled air, and by means of which it experiences a most remarkable change. When in contact with the air, the dark venous blood is converted again into light-red arterial blood, and thereby the *air loses a part of its free oxygen, and receives in return carbonic acid and watery vapour;* the exhaled air is accordingly poor in oxygen, but rich in carbonic acid and vapour. This change of the air is obviously very much like that which the air undergoes by the process of combustion; for in this case, too, its free oxygen is converted into carbonic acid and water. Indeed, this similarity is rendered still more apparent, when we consider, moreover, that *heat becomes free* also in the animal body, as long as it lives and breathes, and that the food received into it, like wood in the fire, entirely disappears, with the exception of a small portion which passes off in the form of excrements. Its disappearance takes place in exactly the same way as that of wood, with which we heat our apartments; this disappearance is caused by a change of the food into aeriform combinations, into carbonic acid and vapour, which are partly exhaled by the lungs, and partly evaporated from the skin.

For this purpose, as it seems, non-nitrogenous food, namely, starch, sugar, gum, fat, lactic acid, and other organic acids, beer, wine, &c., are principally employed, and are therefore called *elements of respiration.*

It is different with those substances which contain nitrogen, sulphur, and phosphorus; these serve for the production of blood, the constituents of which are the same. These substances, albumen, fibrine, &c., afterwards pass with the blood into all parts of the animal body, and are transformed into flesh, nerves, muscle, hair, nails, &c. For this reason, they have been called the *plastic elements of nutrition.* Those nitrogenous, sulphurised, and other substances, such as salts, which can no longer be used in the animal body, are removed from it again by the solid excrements and the urine.

IV. THE FLESH.

What is commonly called *meat* (muscle) is likewise (see § 637) *animal fibrine* or *muscular fibre.* In this form it consists of bundles of fine fibres, which are interwoven with cellular tissue, nerves, and vessels, and are thoroughly penetrated with a watery liquid, the so-called juice of flesh.

640. *Juice of Flesh.—Experiment.*—Mince a quarter of a pound of lean meat very fine, pour over it a quarter of a pound of water, and, after letting it stand fifteen minutes, press out the liquid through a linen cloth; pour over the residue the same quantity of water, squeeze out the liquid, and mix this with the former liquid. In the reddish *juice* are contained almost all the soluble, and, at the same time, all the savoury and odorous constituents of the flesh. If this juice is heated to 140° F. (60° C.), a frothy mass separates from it, which consists of coagulated *albumen.* When the liquid filtered off from this is boiled for some time, a turbidness again ensues, which is caused by the *colouring matter* and *fibrine* (§ 636) of the blood simultaneously extracted from the flesh, which likewise coagulate at a boiling heat. The acid broth now remaining behind contains free phosphoric and lactic acids, phosphate and lactate of the alkalies (much potassa, little soda), phosphate of magnesia, together with several organic matters, a crystalline, indifferent organic body *(creatine)*, and a crystalline, basic, organic body *(creatinine)*, neither of which has been yet thoroughly investigated. By evaporation the broth becomes yellow, and finally brown; if evaporated to dryness, a dark brown soft mass *(extract of flesh)* remains behind, half an ounce of which is sufficient to convert one pound of water, to which some common salt has been added, into a strong and savoury soup.

641. *Muscular Fibre.—Experiment.*—If you boil the fleshy residue left after the former experiment with water for some

hours, you obtain a liquid which coagulates in the cold to a jelly, and consists principally of a solution of *gelatine;* the fat floating on the surface proceeds from the tallow, or fat of the flesh. What remains is *muscular fibre,* a milk-white, hard, tasteless, and inodorous fibrous mass; in this hardened state it is difficultly digestible, and but slightly nutritious.

The annexed grouping gives an approximative idea of the *quantitative* composition of the flesh. From one thousand pounds of beef were obained,—

a.)	By extraction with water (consisting one half of albumen)	60 lbs.
b.)	By five hours' boiling with water (consisting chiefly of gelatine)	6 "
c.)	Lean, juiceless, and tasteless muscular fibre	164 "
d.)	Fat or tallow	20 "
e.)	Water	750 "
		1000 lbs.

642. *Boiling of Meat.*—To obtain by boiling an excellently tender, savoury, and nutritious meat, care must be taken that the juice of the flesh is *not* extracted from the flesh during boiling, but remains in it, and that the boiling is not continued too long. If the *albumen* contained in the juice remains in the interstices of the muscular fibres, a tender roast or boiled meat is obtained; but if, during the boiling or roasting, the juice goes into the broth or gravy, then the meat becomes tough and hard. It is best to put the meat to be boiled into boiling water, continue the boiling for a few minutes, and then let it stand for some hours on some part of the fireplace, where the temperature is about 158° F. (70° C.) In this way the albumen in the external layers of the meat is immediately coagulated by the boiling water, and forms, in this coagulated state, a coating which prevents the escape of the juice, and likewise the penetration of the external water into the interior of the meat.

643. *Preparation of Broth or Soup.*—We must proceed in just the opposite way if we wish to obtain a good and abundant soup from the meat. To effect this, mince the meat fine, mix it uniformly with an equal weight of cold water, heat it slowly to ebullition, let it boil for a few minutes, and finally strain off and squeeze out the liquid. By adding to this liquor

some common salt, and other ingredients with which soups are commonly seasoned, and then colouring it somewhat darker with onions burnt brown, or with burnt sugar, to give it the ordinary favourite brownish colour, we obtain the best soup which can, be prepared from a given quantity of meat. Hitherto, it has been frequently assumed that gelatine formed the most important, most characteristic constituent of meat-soup; but this is a mistake, since the gelatine itself is quite tasteless, and forms but a very insignificant part of the soup. And for this reason, the so-called portable soup prepared in England and France cannot constitute a really good meat-soup.

644. *Salting of Meat.*—A universally-known method of preserving meat is to salt it down, that is, to rub into it and strew over it some common salt, and let it remain piled up, or pressed together, for some time. The common salt extracts from one third to one half of the juice of the meat, dissolves in it, and forms with it the so-called *brine*. Since, consequently, a large portion of the nutritive albumen, and of the lactates and phosphates essential to digestion and nourishment, and also of the creatine and creatinine, are removed with this brine from the meat, the latter must lose in nutritive power, and it is not improbable that this is the reason why a long-continued diet of salt meat—as during sea-voyages—is followed by scurvy and other maladies. Hence, it would be better not to let the salting of the meat continue till brine is formed.

V. THE BILE.

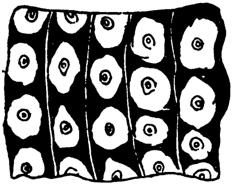
645. The bile separates in the liver from the venous blood; it consists of a thickish, greenish-yellow liquid, and possesses a very bitter taste. Its chief constituents are *choleic acid* and *soda*, which, combined with each other have a saponaceous character. If you shake up bile with water, the solution froths like soapsuds; it also comports itself like this towards greasy substances, and therefore is frequently used for washing silks, which, by the application of soap, would lose their colour. The dried gall-bladder of the carp, with its contents, forms an article of commerce.

Experiment.—Dissolve a little *carp-gall*, or some drops of fresh ox-gall, in a little water, and add gradually to the solution sufficient common sulphuric acid to entirely redissolve the precipitate formed; if you now add a few drops of sugared water, or thin starch-paste, the liquid, unless rendered too hot by the addition of sulphuric acid, assumes a splendid violet-colour. In this way, extremely small quantities of sugar or starch, or, inversely, of bile, may be detected.

VI. THE SKIN.

646. The entire body of animals is externally surrounded by the solid elastic *skin*, which consists of a thick tissue of cells, between which are small openings (pores). The annexed figure represents a piece of human skin about the size of a lentil, as it appears under a powerful magnifying-glass. Partly an oily substance, and partly the watery perspiration, together with some carbonic acid, are separated from the body through the pores.

Fig. 217.



Experiment.—Put a piece of fresh animal skin in water; it swells up in it without dissolving; if kept for some time, it undergoes putrefactive decomposition. If, however, the skin is boiled for some hours with water, the largest part of it dissolves, and we obtain a liquid which, on cooling, *coagulates into a tremulous jelly*. When dried, this forms the well-known *glue*. The skin does not contain glue ready formed, but a tissue, which is only transformed into glue after long boiling, and has received the name of *gelatinous tissue*.

647. *Gelatinous matter* forms a principal constituent of the animal body, for it is found in almost all those parts of it which do not belong to the albuminous substances; for instance, in the inner skin, the muscles, the tendons and ligaments, the bones, horns, &c. Its composition is very nearly that of albumen or animal fibrine; like these, it is *very rich in nitrogen*, and contains also some sulphur, but it is distinguished from them essentially by its properties, and its behaviour towards other substances.

Glue.—Common, amorphous carpenter's glue is mostly prepared from refuse skins or bones, either by extraction with hot water, or, better, by steam under pressure. The concentrated hot solution is then allowed to settle, and the thin liquor yields, on cooling, a stiff jelly, which is cut by wires into thin cakes, and placed to dry upon packthread nettings, which give it the well-known grooved appearance.

Experiment.—If you allow glue to lay in cold water, it swells up into an opaque soft mass; if you then heat it, you obtain a complete transparent solution, which, even when a hundred times diluted, stiffens on cooling. The application of glue as an adhesive medium is well known; its adhesive power is much increased by adding to it white lead (Russian glue) or borax (about an ounce or an ounce and a half to a pound of glue.)

Isinglass, also, is one of the gelatinous substances. This consists of the inner membrane of several fishes, particularly of the sturgeon, which, after being cleansed, is dried and brought into the market in the form of plates, or of sticks twisted into the shape of a horseshoe. On boiling, a colourless or inodorous gelatinous solution is obtained from it, which is much used as an adhesive medium, or when smeared upon taffety as court-plaster, or mixed with the juices of fruits and sugar for the preparation of jellies.

The *horns of the deer* are likewise rich in gelatine, and on this account, when rasped, yield, by long continued boiling with water, a liquid which stiffens in the cold (hartshorn jelly).

Small quantities of gelatine occur also in broth and in gravy, and impart to them, especially to the latter, the property of stiffening in the cold to a tremulous jelly.

648. *Gelatine and Tannic Acid.—Experiment.*—If you pour some tincture of galls upon a solution of gelatine, or upon a decoction of meat, you obtain a flaky precipitate, a combination of gelatine with tannic acid, which is insoluble in water, and may remain, whilst wet, exposed to the air without passing into putrefaction. For this reason, gelatine is an excellent means for clarifying liquids, as wine, &c., from any tannin that they may contain.

But this action of tannic acid upon gelatine is of far more importance, as it may be used for converting animal skins into *leather*. The gelatine of the skin is altered in the same manner as the gelatine in the experiment was, when the skins are packed in layers with ground oak or pine bark (tan) in vats, and allowed to remain moistened with water till they are quite saturated with the brown tannin of the bark (*tanning*). This penetration takes place more rapidly by forcibly pressing liquids containing tannin into the skin (*quick-tanning*). The brown sole and upper leather consist, accordingly, of cellular tissue, the gelatine of which has become intimately combined with the tannic acid; it is now, especially when it is saturated with oil or fat, pliable, supple, and almost impervious to water; nor when moist does it undergo putrefaction.

Skins are converted in another manner into leather, by means of certain salts, most frequently by laying them in a solution of alum and common salt, and afterwards working them with fish-oil and other fats; the leather prepared in this way is white, and is softer and more supple than the former (*tawing*). The still softer *wash* or *chamois leather* is obtained by merely working the skins a long time with fat. In this way the Indians also convert the skins of animals into soft leather, by kneading them with the brains of animals steeped in hot water, until the fat contained in the brains has been absorbed by the skin.

If the softened and scraped skins are stretched in frames, and rubbed, while drying, with pumice-stone, till they are quite smooth, the thin, translucent, stiff, and elastic *parchment* is obtained (*hog-skin*). By rubbing with chalk, the parchment becomes white and opaque, by smearing with white lead and varnish, polished and smooth (*writing parchment*).

649. Before the animal skins can be subjected to either of the operations just described, they must be *freed from the hair*. This is easily done by scraping, after the skin has been decomposed either by the influence of moisture and heat, or by caustic lime. Sulphuret of calcium may also be used for this purpose. (§ 405.)

650. Gelatine, like other animal substances in the presence of air and water, very readily passes into *decay* or *putrefaction*, and yields thereby, since it is very rich in nitrogen, much ammonia; therefore it will not appear strange that it powerfully promotes the growth of plants. Its effect may be observed in a truly surprising manner in the hyacinth, if it is occasionally watered with a thin solution of glue, or if the bulbs are surrounded with horn-shavings when planted in the earth.

651. If gelatine is boiled for some time with potassa lye, there is formed from it, together with some other products of decomposition, a peculiar substance, crystallising in needles; it has a very sweet taste, and has received the name of *sugar of gelatine*, or *glycicoll*.

652. There is a kind of gelatine which varies somewhat in its properties from common gelatine; it is obtained from young, not yet fully hardened bones, and from the cartilaginous parts of the animal body,—for instance, from the carti-

lages of the windpipe, of the nose, &c.,—by long boiling with water. This kind of gelatine has received the special name of *chondrine.*

653. *Horny Matter.*—The hair, wool, bristles, feathers, nails, claws, hoofs, horns, scales, &c., which often cover the skin of animals, are not dissolved by boiling with water into gelatine; they very much resemble the latter in their constitution, as, besides nitrogen, they contain also some sulphur. Their containing sulphur is the reason why they become black, when heated with a solution of lead, since a dark sulphuret of lead is formed. *Wool* consists of hollow yellowish tubes, coated with fat. By washing with putrid urine, or soap-water, the fat may be removed; but by sulphurous acid the yellow colour is converted into white (chlorine is not applicable to the bleaching of wool). The fibres of wool, as well as those of silk, which are likewise of animal origin, have a far greater affinity for colouring matter than the vegetable fibres of linen or cotton have; and this is the reason why woollen and silk stuffs may be more easily or permanently dyed than cotton or linen. By boiling with lye, all the above-named animal substances, consisting of horny matter, may be entirely dissolved.

VII.—THE BONES.

The bones forming the solid skeleton of the animal body consist, one-third of organic gelatinous matter, and two-thirds of inorganic matter (bone-earth).

654. *Bone-earth.—Experiment.*—Put a piece of beef-bone, which has been weighed, into a fire, and take it out again when it has entirely recovered its white colour; the gelatine burns away, but the bone-earth remains behind. The *bone burnt to whiteness*, which has become one-third lighter, consists principally of phosphate of lime mixed with some carbonate of lime (magnesia, fluoride of calcium, and chloride of sodium). This proportion between the gelatine and bone-earth is, however, not invariable; it varies in different animals, and indeed even in one and the same animal, according to its age.

655. *Bone-black.—Experiment.*—If you heat a bone for some hours in a crucible which is well covered with a piece of tile, it assumes a black colour; it becomes *bone-black* (ivory-black, &c.). As the air in such cases does not have access to the bone, only imperfect combustion, charring of

the gelatine, takes place; the bone-earth, intimately mixed with the charcoal which is formed, remains behind.

Experiment.—If you add some *diluted muriatic acid* to the bone-black, and let it remain some time in a warm place, the bone-earth will be dissolved, and the charcoal may be separated by filtration, washed, and dried. From one ounce of bone-black only half or three-fourths of a drachm of charcoal is obtained; but this, on account of its minute state of division, possesses such a remarkable bleaching power, that one ounce of bone-black acts far more powerfully than the same quantity of wood-charcoal. If ammonia is added to the filtered liquid, the dissolved phosphate of lime is again precipitated from it as a white powder, because the muriatic acid is neutralised by the ammonia, and thereby loses the power of holding the bone-earth in solution.

656. *Experiment.*—Put a bone in a glass vessel, and pour over it some *diluted muriatic acid*; the bone will gradually become soft and transparent, and finally pass into a cartilaginous transparent mass. The way in which the muriatic acid acts is obvious from the former experiment; it dissolves the bone-earth, and the gelatinous matter remains behind, since it is insoluble in muriatic acid and in water. If the latter is taken from the acid, and, after having been washed, is boiled for some time with water, it is transformed into gelatine, and a solution is obtained which coagulates on cooling. This method is employed in many factories for preparing glue from bones. The acid solution of bone-earth makes an excellent manure. That bone-earth is really dissolved in the acid is readily ascertained by the addition of ammonia.

657. On *boiling bones* with water, in addition to the fat present in all bones, the gelatine, situated in the external portions only, is extracted; but the whole of the gelatine may be removed if the boiling is performed in air-tight vessels, as in this case the water is forced by the increased pressure into the interior of the bones. Steam, also, under great pressure, operates in the same way. Glue is prepared on a large scale by both of these methods.

658. *Bone-dust.*—Unburnt bones ground to a coarse powder (*bone-dust*), and also white or black burnt bones, have for many years been regarded in England as an excellent manure; in Germany it is only in more recent times that their economical value has been recognised. It is very obvious how they enhance the fertility of land; the burnt

bones furnish the soil, by means of the bone-earth, with two inorganic substances, *lime* and *phosphoric acid,* which every plant requires for its development; the unburnt bones, moreover, by means of their gelatinous matter, furnish *ammonia.*

VIII.—THE SOLID EXCREMENTS AND URINE.

659. Those ingredients of the food consumed, which are not applicable to nourishment, that is, which cannot be converted into the constituents of the animal body, and those parts which are separated from the body (as no longer serviceable to the vital process) by the incessant process of renovation, which we call life, are either removed from the body in an aeriform state, by *breathing,* or *insensible perspiration,* or in a liquid form, as *urine,* or, finally, in a solid form, that of the *solid excrements.* Both of the last-named substances are of great import in medicine and domestic economy; in medicine, because the physician, in cases of sickness, is frequently able, by their condition, to ascertain the nature of a disease; in domestic economy, because the farmer makes use of them for promoting the growth of plants.

The *solid excrements* (fæces) consist, for the most part, of those constituents of the food which are not dissolved in the stomach,—not digested; in the herbivorous animals, principally of vegetable tissue, chlorophyll, wax, and insoluble salts; in the carnivorous animals, dogs, for instance, frequently almost wholly of inorganic substances, as phosphate of lime, magnesia, &c., mixed with but a very small quantity of organic matter. The beneficial influence of solid excrements on vegetation is principally owing to the inorganic compounds contained in them (lime and magnesia, phosphoric acid, and silicic acid).

660. By the *urine,* which is separated in the kidneys from the arterial blood, the *soluble salts* contained in food, and also the *nitrogen* no longer necessary for the vital process, are removed again from the body; it is natural, therefore, that the constituents of it, as likewise of the fæces, should depend upon the food consumed. If this is rich in soluble salts, the urine will also be rich in them; if this contains only a few soluble, but many insoluble salts, the urine will be poor in soluble salts, while the fæces will be rich in insoluble salts. Consequently, the amount of inorganic substances in the animal excrement or manure may be just

as accurately ascertained from the food which the animal consumes, as from the manure itself. The food has only to be burnt, and the remaining ashes examined; those parts of it which are soluble in water correspond with the salts in the urine; those which are insoluble, to the organic substances of the fæces. We find in the urine of cows and horses, principally alkaline carbonates, muriates, and sulphates (potassa, soda, and ammonia); in the urine of men, moreover, some alkaline phosphates.

661. *Nitrogen* is contained in the urine, either in the form of urea, uric acid, or hippuric acid. Urine, like the juice of flesh, contains, moreover, creatine and creatinine. (§ 640.)

Urea occurs in the greatest abundance in the urine of the higher animals, especially in the carnivorous quadrupeds. It crystallises in colourless needles, or prisms, and is easily soluble in water. This substance has excited great scientific interest, as it is the first organic compound which has been artificially prepared. Thus, it was found that *cyanate of ammonia,* without losing any of its constituents, or receiving any new ones, was converted, merely by heat, into urea.

$$\begin{array}{r}\text{From Cyanic Acid} = \\ \text{and Ammonia} = \\ \text{was formed}\end{array}\;\underbrace{\begin{array}{r}\text{Carbon, Oxygen, Nitrogen,}\\ \text{Nitrogen, Hydrogen,}\end{array}}_{\text{Urea.}}$$

In a practical point of view, that decomposition which urea undergoes in urine, when the latter putrefies by long standing in the air, is of great importance. During this decomposition the urea combines with the constituents of two atoms of water, and becomes thereby *carbonate of ammonia.* From

$$\begin{array}{r}\text{Urea} = \\ \text{and Water} = \\ \text{are formed}\end{array}\;\underbrace{\begin{array}{c}\text{Carbon, Oxygen,}\\ \text{Oxygen,}\end{array}}_{\text{Carbonic Acid}}\;\text{and}\;\underbrace{\begin{array}{c}\text{Nitrogen, Hydrogen,}\\ \text{Hydrogen,}\end{array}}_{\text{Ammonia.}}$$

662. *Uric acid* (*lithic acid*) predominates in the urine of the lower animals; the white excrements of birds and snakes (a mixture of fæces and urine) consist chiefly of urate of ammonia. In the pure state, it consists of fine white crystalline scales, which are dissolved in water only with extreme difficulty. On account of this difficult solubility it sometimes separates spontaneously from the urine (gravel and urinary calculi). If those excrements which are rich in uric acid are allowed to remain for some time exposed to the air, they will absorb oxygen, and afterwards contain *oxalate of ammonia.* If the latter takes up more oxygen, it passes over into *car-*

bonate of ammonia. Thus is explained why we frequently find in some sorts of guano only traces of uric acid, but instead of it large quantities of oxalates.

663. *Guano (bird's dung).*—Guano, which in recent times has been in such demand as a manure, owes its efficacy chiefly to the *uric acid* contained in it, or, if this has already undergone decomposition, to the *ammoniacal salts* formed from it, and in part also to the inorganic *salts* (sulphate, phosphate, and muriate of potassa, soda, lime, magnesia, &c.) present in it. On account of the great difference in the article, it is indispensable that the farmer should test it before its application. This is done with sufficient accuracy for agricultural purposes in the following way:

Experiment a.—Pour some strong vinegar over guano; no perceptible effervescence should ensue. A brisk effervescence would indicate an admixture of carbonate of lime.

Experiment b.—Heat half an ounce of guano in an iron spoon over a spirit-lamp, or upon glowing charcoal, till it is burnt to a white ash; good guano should only leave behind, at the most, one drachm of ashes. The amount of alkaline salts this ash contains, may be ascertained by extraction with hot water; what remains consists of earthy (lime and magnesia) salts. The inferior sorts of guano often yield, after burning, three-fourths of their weight of ash.

Experiment c.—Treat half an ounce of pulverised guano several times with hot water, and decant the liquid after it has become clear on settling; then dry and weigh the muddy mass which finally remains; it should not weigh more than a quarter of an ounce.

664. *Hippuric Acid.*—This nitrogenous acid always occurs in the urine of herbivorous animals; it crystallises in long white needles, and is difficultly soluble in water. On the putrefaction of the urine, it is converted into benzoic acid and ammonia.

Human urine contains all three of the above-mentioned highly nitrogenised compounds, viz., urea, uric acid, and hippuric acid; the first, urea, exists in the largest quantity.

665. When urine remains for some time exposed to the air, it undergoes a decomposition, in which volatile substances having a disagreeable odour are formed; it passes into *putrefaction.* It is obvious from what has been stated, that *carbonate of ammonia* is to be regarded as the principal

product of this decomposition (putrid urine contains, moreover, creatine). Putrid urine may, therefore, be employed for the cleansing of wool, and for the preparation of chloride of ammonium. (§ 233.) This change takes place when urine collects in dung-heaps, or is poured upon the soil. To prevent the evaporation of the volatile carbonate of ammonia, it is well to add gypsum, diluted sulphuric acid, or green vitriol, from time to time, to the manure-heaps, by which means sulphate of ammonia is formed, which does not escape at the ordinary temperature. In this respect, also, an addition of substances rich in carbon, for instance, bone-black, earthy brown-coal, peat, &c., acts very beneficially, because the carbonaceous matter first retards the putrid decomposition, and afterwards retains the gases hereby formed (carbonic acid, ammonia, sulphuretted hydrogen, &c.). The inorganic salts of the urine, and of the solid excrements, are not essentially altered by the putrefaction. To these *salts* and to the *nitrogen* are principally to be ascribed the beneficial effects which animal manure exercises on the fertility of our fields.

RETROSPECT OF ANIMAL MATTER IN GENERAL.

1. A constant motion is taking place in the living animal, as well as in the living plant,—an incessant reception (eating, drinking and breathing), change (digestion, assimilation), and separation (secretion, excretion) of aeriform, liquid, and solid bodies.

2. In a chemical point of view, *animal life* is distinguished from vegetable life principally by the uninterrupted reception of oxygen, and separation of carbonic acid and water. (Among the Infusoria, however, there are some which exhale oxygen.) During the life of *plants*, on the contrary, carbonic acid and water are received, and oxygen separated.

3. Besides water, air, and some salts, those substances only serve for the nutrition of the animal body which are produced by means of vegetable or animal life. The plant consumes carbonic acid, the animal vegetable tissue, sugar, gum, fat, &c.; the plant consumes ammonia, the animal albuminous substances, for instance, gelatine, albumen, caseine, flesh, blood, &c.

4. The first series of the above-named articles of food, that of those rich in carbon, serves for the maintenance of

the respiratory or destructive process, and for the production of animal heat (elements of respiration); the second class, that of the articles of food rich in nitrogen, serves for the maintenance of the nutritive or formative process (plastic elements of nutrition).

5. Animal substances may be divided:

I. According to their *composition*,—

a.) Into non-nitrogenous substances (fat, sugar of milk, &c.).

b.) Into nitrogenous albuminous substances (albumen, caseïne, flesh, fibrine, &c.).

c.) Into nitrogenous gelatinous substances (gelatine of the bones, ligaments, gristle, &c.).

d.) Into nitrogenous excreted substances (urea, uric acid, hippuric acid, &c.).

II. According to their *occurrence* and their *production* in the animal body,—

a.) Into products of the process of digestion.
b.) " " " respiration.
c.) Constituents of the red blood.
d.) " of the white blood (lymph).
e.) " of the flesh, &c.
f.) " of the bones, &c.
g.) " of the skin, hair, &c.
h.) " of the products of secretion and excretion (bile, milk, urine, &c.).

6. *The changes undergone by animal matters* from the influence of heat, water, air, acids, bases, &c., exceed in variety those of vegetable matters, since they are far more complex than the latter; they agree in the most important respects with those which the nitrogenous and sulphurised vegetable substances experience.

7. The spontaneous changes of animal and vegetable matter may be arrested,—

a.) By the removal of the *water* (drying, baking, &c.).

b.) By exclusion of *air* (Appert's method of preservation, bottling of beer, wine, &c.).

c.) By reducing the *temperature* below the freezing point (refrigerators, &c.).

d.) By antiseptics; as common salt, nitre (salting), wood-vinegar, creosote (smoking), alcohol, sugar, charcoal; and arsenical, mercurial, and other metallic compounds.

A SYNOPSIS

OF THE MOST IMPORTANT TESTS FOR ASCERTAINING THE PRESENCE OF THE MORE COMMON CHEMICAL COMPOUNDS, ESPECIALLY WHEN IN SOLUTION.

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1. *Alkalies and their Salts.*

THESE are not precipitated by carbonate of ammonia, sulphuretted hydrogen ($H\ S$), or hydrosulphuret of ammonia ($N\ H_3,\ H\ S$).

2. *Salts of Potassa.*

Tartaric acid, in excess and in a concentrated solution, produces, especially after violent agitation, a white crystalline precipitate. (Tartar, § 194.)

Platinum solution gives a yellow crystalline precipitate. (Chloride of platinum and potassium, § 394.)

3. *Salts of Soda.*

Antimoniate of potassa produces, in neutral or alkaline solutions of soda salts, a white precipitate. (Antimoniate of soda, § 404.)

4. *Salts of Ammonia.*

Caustic lime or *caustic potassa*, especially on heating, liberates the ammonia, which is easily recognised by its pungent odour. Heated on platinum foil, the salts of ammonia are readily volatilised. (§ 229.)

Platinum solution reacts in the same manner as with potassa salts. (§ 392.)

5. *Alkaline Earths.*

These are precipitated by *carbonate of ammonia*, as carbonates of a white colour, but not by $H\ S$ or $N\ H_3,\ H\ S$.

6. *Salts of Baryta and Strontia.*

Sulphuric acid produces a white precipitate, insoluble in acids (sulphate of baryta and of strontia). The baryta salts impart a yellowish colour, and the strontia salts a crimson colour to the flame of alcohol. (§ 248.)

7. *Salts of Lime.*

Sulphuric acid produces only in concentrated solutions of lime a precipitate, which is redissolved in a large proportion of water. (§ 241.)

Oxalic acid and ammonia indicate mere traces of lime by a milky turbidness. (Oxalate of lime, § 197.)

8. *Salts of Magnesia.*

Sulphuric acid causes *no* precipitate nor turbidness. (§ 249.)

Phosphate of soda and ammonia produce, but not immediately in diluted solutions, a white crystalline precipitate. (Phosphate of magnesia and ammonia, § 251.)

9. *Salts of Alumina.*

These are precipitated by *ammonia*, *carbonate of ammonia*, and also by $N H_3, H S$, as hydrate of the oxide of alumina. *Potassa* in excess dissolves the hydrate of oxide of alumina, which is again precipitated by *chloride of ammonium*. (§ 260.) They are coloured blue on being heated to redness with cobalt solution. (§ 262.)

10. *Metallic Salts.*

Ammonia precipitates the oxides from their solutions as hydrates; *carbonate of ammonia* also precipitates them (partly as carbonates and partly as hydrated oxides).

$H S$ added to an acid solution precipitates the following metallic oxides as sulphurets:

a.) Black; lead, bismuth, copper, silver, mercury, platinum, gold.

b.) Dark brown; tin (protoxide).

c.) Orange; antimony.

d.) Yellow; tin (peroxide), cadmium, arsenic.

Of these, the sulphurets of platinum, gold, tin, antimony, and arsenic, are soluble in $N H_3, H S$.

NH_3, HS precipitates also as sulphurets the following, which are not precipitated by sulphuretted hydrogen alone from their acid solutions:

a.) Black; iron, cobalt, nickel.

b.) Flesh-coloured; manganese.

c.) White; zinc (also alumina and oxide of chromium as hydrates).

11. *Salts of Protoxide of Iron.*

Ammonia; a greenish-white precipitate, which becomes dark green, and finally reddish-brown. (Hydrated protoxide of iron, § 285.)

Ferrocyanide of Potassium; a pale blue precipitate, becoming finally dark blue. (§ 292.)

Tincture of gall-nuts; a violet precipitate, passing gradually to bluish-black. (Tannate of protoxide of iron, § 285.)

12. *Salts of Sesquioxide of Iron.*

Ammonia; a reddish-brown precipitate. (Hydrated sesquioxide of iron, § 285.)

Ferrocyanide of potassium; a dark-blue precipitate. (Prussian blue, § 292.)

Tincture of galls; a bluish-black precipitate. (Tannate of sesquioxide of iron, § 285.)

13. *Salts of Manganese.*

Ammonia; a white precipitate, soon passing to light and then dark brown. (Hydrated protoxide of manganese, § 300.)

HS; a flesh-coloured precipitate. (Sulphuret of manganese, § 300.)

14. *Salts of Cobalt.*

Potassa; a blue precipitate, gradually becoming green. (§ 307.)

Blow-pipe; melted with borax, they give a blue bead. (Cobalt glass, § 304.)

15. *Salts of Nickel.*

Potassa; a light green precipitate. (Hydrated protoxide of nickel, § 307.)

16. *Salts of Zinc.*

Ammonia; a gelatinous white precipitate (hydrated oxide of zinc), which redissolves in an excess of ammonia; white sulphuret of zinc is precipitated from this solution by $N H_3, H S$.

Blow-pipe; heated with carbonate of soda upon charcoal, a yellow incrustation is formed, which becomes white on cooling. (Oxide of zinc, § 310.)

17. *Salts of Tin.*

Solution of gold causes in solutions of protoxide of tin a purplish red colour or precipitate. (Gold purple, § 322.)

$H S$; in solutions of the protoxide, a dark-brown precipitate (protosulphuret of tin); in solutions of the perchloride, a yellow precipitate. (Bisulphuret of tin, § 325.)

18. *Salts of Lead.*

Sulphuric acid; a white precipitate insoluble in acids. (Sulphate of lead.) The same is immediately rendered black by $N H_3, H S$. (§ 335.)

Blow-pipe; heated with carbonate of soda upon charcoal, malleable metallic beads are formed, together with a yellow incrustation upon the charcoal. (§ 331.)

19. *Salts of Bismuth.*

Water, added largely to solutions of bismuth, causes a white turbidness, with the precipitation of a basic salt of bismuth. (§ 347.)

Blow-pipe; if heated with carbonate of soda upon charcoal, brittle metallic beads are obtained. (§ 345.)

20. *Salts of Copper.*

Ammonia causes a greenish-blue precipitate, which redissolves in an excess of ammonia, forming a deep blue liquid. (§ 353.)

Ferrocyanide of potassium; a copper-red precipitate. (Ferrocyanide of copper, § 292.)

Polished iron; a deposition of metallic copper. (§ 152.)

Blow-pipe; when heated with carbonate of soda upon charcoal, and washed with water, spangles of metallic copper are obtained. (§ 355.)

21. *Salts of Mercury.*

Potassa precipitates from salts of the protoxide, black protoxide of mercury (§ 368); from salts of the peroxide, yellowish-red peroxide of mercury. (§ 371.)

Protochloride of tin, on boiling, precipitates metallic mercury. (§ 375.)

Copper, on being rubbed with a solution of mercury, assumes a silvery appearance. (§ 369.)

22. *Salts of Silver.*

Muriatic acid; a white, curdy precipitate, soluble in ammonia. (Chloride of silver, § 381.)

Blow-pipe; heated with carbonate of soda upon charcoal, glistening malleable metallic beads are formed. (§ 381.)

23. *Salts of Gold.*

Protochloride of tin; a purple-red precipitate. (Gold purple, § 388.)

Green vitriol; a precipitate of gold powder. (§ 387.)

24. *Salts of Platinum.*

Potassa; a yellow crystalline precipitate. (Chloride of platinum and potassium, § 394.)

Blow-pipe; reduces the salt to a metal. (§ 392.)

25. *Salts of Sesquioxide of Chromium.*

Potassa; a bluish-green precipitate (hydrated oxide of chromium), soluble in an excess of potassa, forming a dark green solution. (§ 400.)

26. *Salts of Chromic Acid.*

Sugar of lead; a yellow precipitate. (Chrome yellow, § 399.)

Sulphuric acid and alcohol; conversion of the yellow or red colour into green by heat. (§ 400.)

27. *Compounds of Antimony.*

H S; an orange-coloured precipitate. (Sulphuret of antimony, § 407.)

Blow-pipe; heated with carbonate of soda, brittle metallic globules are formed; and also white fumes and a white incrustation upon the charcoal. (§ 403.)

Marsh's test. (§ 418.)

28. *Compounds of Arsenic.*

H S; a yellow precipitate. (Sulphuret of arsenic, § 416.)

Reduction test. (§ 413.)

Marsh's test. (§ 417.)

29. *Salts of Sulphuric Acid.*

Chloride of Barium; a white pulverulent precipitate, insoluble in acids. (Sulphate of baryta, § 171.)

Sugar of lead; a white precipitate, insoluble in diluted acids. (Sulphate of lead, § 335.)

30. *Salts of Sulphurous Acid.*

Sulphuric Acid evolves a gas having the odour of burning sulphur. (§ 174.)

31. *Salts of Phosphoric Acid.*

Chloride of barium; a white precipitate, soluble in acids.

Silver solution; a yellow precipitate. (Phosphate of silver, § 176.)

Solution of magnesia and ammonia; a white precipitate. (See No. 8.)

32. *Salts of Boracic Acid.*

Chloride of barium; a white precipitate, soluble in acids.

Sulphuric acid and alcohol, when heated with them, present a green flame. (§ 182.)

33. *Salts of Nitric Acid.*

Indigo solution and sulphuric acid; by boiling, the pale blue liquid is destroyed by the liberated nitric acid.

Glowing charcoal causes a deflagration of the nitrates. (§ 207.)

34. *Salts of Chloric Acid*

Act like the nitrates towards *solution of indigo,* and upon glowing charcoal; but, when heated with muriatic acid, they evolve the odour of chlorine. (§ 150.)

35. *Chlorides or Salts of Muriatic Acid.*

Silver solution; a white, curdy precipitate of chloride of silver, readily soluble in ammonia. (§ 186.)

Peroxide of manganese and sulphuric acid; evolution of chlorine on heating. (§ 151.)

36. *Iodides.*

Silver solution; a yellowish precipitate of iodide of silver, difficultly soluble in ammonia.

Peroxide of manganese and sulphuric acid evolve iodine in violet fumes. (§ 210.)

Starch paste and nitric acid; blue colour. (Iodide of starch, § 155.)

37. *Sulphurets.*

Muriatic acid evolves from most of them a gas having the odour of rotten eggs. (H S, §§ 132, 213.)

38. *Salts of Carbonic Acid.*

Muriatic acid liberates from them with effervescence an inodorous gas. (§§ 202, 237.)

Lime-water is rendered milky by them. (Carbonate of lime, § 115.)

39. *Salts of Oxalic Acid.*

Solution of sulphate of lime causes a white precipitate. (Oxalate of lime, § 197.)

Heated upon platinum foil, they are decomposed without carbonisation. (§ 197.)

40. *Salts of Tartaric Acid.*

Potassa precipitates tartar, as in No. 2. (§ 194.)

Heated on platinum foil, they are decomposed with separation of much carbon, and give off the odour of burnt sugar. (§ 194.)

41. *Salts of Acetic Acid.*

Sulpuric acid produces on heating an odour of vinegar.

Sulphuric acid and alcohol, an odour of acetic ether. (§ 198.)

Heated, they are carbonised, and give off the odour of vinegar. (§ 198.)

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THE END.

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